PLEASE BRING THIS PROGRAM TO THE MEETING

The Geological Society of America
Cordilleran Section

The Seismological Society of America

The Paleontological Society
Pacific Coast Section

University of British Columbia, Vancouver, British Columbia

MAY 5-9, 1960

GENERAL ANNOUNCEMENTS

Registration and Information: All persons are requested to register in the Common Block, Men's Residences, University of British Columbia, on Wednesday afternoon, May 4, from 1 o'clock until 6, and on Thursday, May 5, beginning at 8:00 a.m. Registration thereafter will be in the lobby of the Buchanan Building. A fee of $3 will be charged all who attend the scientific sessions and field trips.

Cordilleran Section (GSA) Business Meeting and Luncheon: Noon, Saturday, May 7, at Brock Hall. Open to Fellows and Members

Pacific Coast Section (PS) Business Meeting and Luncheon: Noon, Friday, May 6, at Brock Hall

Seismological Society Business Meeting and Luncheon: Noon, Friday, May 6, Brock Hall

Visiting Ladies: All visiting ladies are invited to attend the field trip on Thursday, May 5. On Friday and Saturday, May 6 and 7, special arrangements will be made to entertain the ladies, through a local committee headed by Mrs. H. V. Warren.

Annual Banquet: All societies will participate in the Annual Banquet on Friday evening, May 6, at Brock Hall. Dr. W. C. Gussow of Calgary, Alberta, will be the speaker of the evening.

Field Trips: Final information will be available at the Registration Desk, as will a Guidebook especially prepared for the meeting. The following trips are planned:

1. Howe Sound (Vancouver to Squamish), Thursday, May 5. Leaders: J. E. Armstrong and J. V. Ross
2. North Vancouver Dam Sites, Thursday, May 5. Leaders: V. Dolmage and D. D. Campbell
3. Kamloops-Fraser Canyon, Saturday, May 7, to Monday, May 9. Leaders: K. C. McTaggart, C. S. Ney, J. M. Carr, G. E. Rouse

Outline of Meeting

Registration	
Wednesday, May 4, 1–6 p.m., and Thursday, May 5, beginning at 8 a.m.	Common Block, Men's Residences
Friday and Saturday	Lobby, Buchanan Building
Scientific Sessions (All sessions in Buchanan Building)	
Areal Geology — Saturday, 8:30 a.m.	Room 102
Engineering Geology — Friday, 10:00 a.m.	Room 100
General Session — Thursday, 9:30 a.m.	Room 106
Mineralogy and Geochemistry — Friday, 1:30 p.m.	Room 102
Paleontology — Friday, 1:30 p.m.	Room 100
Petrology — Friday, 10:00 a.m.	Room 106
Petrology of the Northwest — Saturday, 8:30 a.m.	Room 106
Seismology — Friday, 8:30 a.m.; Friday, 1:30 p.m.; Saturday, 8:30 a.m.	Room 104
Stratigraphy — Saturday, 8:30 a.m.	Room 100
Structural Geology — Friday, 1:30 p.m.	Room 106
Symposium: Eugeosyncline of the Western Cordillera — Saturday, 1:30 p.m.	Room 106

Field Trips (Final Information Available at Registration Desk)

1. Howe Sound—Thursday, 8:00 a.m.
2. North Vancouver Dam Site—Thursday, 8:00 a.m.
3. Kamloops-Fraser Canyon—Saturday through Monday

Business Meetings and Luncheons	
Pacific Coast Section of Paleontological Society, Friday noon; Seismological Society of America, Friday noon; Cordilleran Section of the Geological Society, Saturday noon	Brock Hall
Banquet	
Friday evening, 7:00	Brock Hall

Ladies' Entertainment

Final Information at the Registration Desk

Officers for 1960

The Geological Society of America, Cordilleran Section

Chairman: Gordon Oakeshott
Vice-Chairman: Peter Misch
Secretary: V. L. VanderHoof

The Seismological Society of America

President: Charles F. Richter
First Vice-President: James T. Wilson
Second Vice-President: Dean S. Carder
Third Vice-President: Frank Press
Secretary: Karl V. Steinbrugge
Treasurer: William K. Cloud

Paleontological Society, Pacific Coast Section

Chairman: R. L. Langenheim, Jr.
Vice-Chairman: H. J. Bissell
Secretary: D. L. Jones
Councilor: John Lance

Local Committee

Chairman: W. H. Mathews
Treasurer: J. E. Armstrong
Ladies' Entertainment: Mrs. H. V. Warren
Members: W. R. Danner
J. A. Gower
R. C. Macdonald

Program Committee

V. J. Okulitch (Chairman), *University of British Columbia*
J. E. Armstrong, *Geological Survey of Canada, Vancouver*
Howard Coombs, *University of Washington, Seattle*
W. H. Mathews, *University of British Columbia, Vancouver*
Peter Misch, *University of Washington, Seattle*
V. L. VanderHoof (Secretary), *Museum of Natural History, Santa Barbara*

Student Assistants

David J. Carson
Ray L. Cox
A. Darryl Drummond
Pierre L. Gauvin
William D. Groves
Claude Hubert
Donald W. Hyndman
Rodney V. Kirkham
Sydney B. Lumbers
Brande Matson
Kenneth L. Roy
Darcy L. Scott
Alastair Sinclair
Alan D. Stanley
Clyde L. Smith
William D. Tedlie
R. Bruce Vaughn
Raymond L. Yole

Scientific Sessions

FRIDAY MORNING

8:30 Seismology

Room 104, Buchanan Building

Cochairmen: James T. Wilson and W. G. Milne

1. Karl V. Steinbrugge: *Engineering notes on the Hebgen Lake, Montana, earthquake of August 17, 1959*
2. George H. Sutton, Robert W. Metsger, and Jack Oliver: *Earth-strain meter installation at Ogdensberg, New Jersey*
3. William Stauder, S.J.: *Focal mechanism of three Kamchatka earthquakes*
4. George G. Shor, Jr.: *Seismic-refraction studies at sea near southern and western Alaska*
5. John E. Nafe and James N. Brune: *Observations of phase velocity for Rayleigh waves in the period range 100–400 seconds*
6. William K. Cloud: *Earthquake recorded by low-cost instrument*

9:30 General Session

Room 106, Buchanan Building

Chairman: Vladimir J. Okulitch

1. Address of Welcome. Dr. N. A. M. MacKenzie, President of the University
2. Introduction of Officers of the Societies
3. Announcements of General Interest

10:00 General Petrology

Room 106, Buchanan Building

Cochairmen: I. McTaggert and Aaron Waters

1. Fred N. Houser* and F. G. Poole: *Primary structures in pyroclastic rocks of the Oak Spring formation (Tertiary), northeastern Nevada Test Site, Nye County, Nevada* (20 minutes)
2. Edgar H. Bailey* and Rollin E. Stevens: *Selective staining of plagioclase and K feldspar on rock slabs and thin sections* (15 minutes)
3. D. O. Emerson: *Modal variations within an outcrop of the Sagehen adamellite* (10 minutes)
4. Salem J. Rice: *Tourmalinized Franciscan sediments at Mt. Tamalpais, Marin County, California* (15 minutes)
5. William N. Laval* and Allan E. Miller: *Porphyry intrusive rocks of the Manhattan district, Northern Front Range, Colorado* (15 minutes)
6. K. D. Watson: *Eclogite inclusions in serpentine pipes at Garnet Ridge, northeastern Arizona* (10 minutes)
7. W. G. Ernst: *Diabase–granophyre relations in the Endion sill, Duluth, Minnesota* (15 minutes)

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* Speaker

10:00 Engineering Geology

Room 100, Buchanan Building

Cochairmen: D. Campbell and R. Treasher

1. J. E. Armstrong: *Geology of proposed Columbia River dam sites, British Columbia* (20 minutes)
2. J. Hoover Mackin: *Geology of the Priest Rapids and Wanapum dam sites on the Columbia River in south-central Washington* (15 minutes)
3. Howard A. Coombs* and C. R. Hoidal: *Geologic problems at the Gorge High dam, Skagit River, Washington* (15 minutes)
4. E. C. Marliave: *Foundation failure at Malpasset Dam near Frejus, France* (15 minutes)
5. Allen S. Cary: *Rockfill dams* (15 minutes)
6. Ronald L. Shreve: *Geology of the Blackhawk landslide, Lucerne Valley, California* (15 minutes)

FRIDAY AFTERNOON

1:30 Structural Geology

Room 106, Buchanan Building

Cochairmen: V. Gianella and R. Jahns

1. Vincent P. Gianella: *Faulting in northeastern Sonora, Mexico in 1887* (15 minutes)
2. Richard H. Jahns* and Lauren A. Wright: *Garlock and Death Valley fault zones in the Avawatz Mountains, California* (15 minutes)
3. Robert R. Compton: *Relations of major folds and reverse faults in Santa Lucia Range, California* (15 minutes)
4. Lehi F. Hintze: *Thrust-faulting limits in western Utah* (15 minutes)
5. Robert E. Wallace,* Norman J. Silberling, and Donald B. Tatlock: *Structural features of the Humboldt Range, Nevada* (20 minutes)
6. Peter Misch: *Large overthrusts in the northwestern Cascades near the 49th parallel* (*Whatcom and Skagit counties, Washington, and Tomyhoi Creek area, British Columbia*) (20 minutes)
7. E. W. Mountjoy: *Regional structure of Rocky Mountains in the Jasper area, Canada* (15 minutes)
8. Ernest H. Lathram: *Patterns of structural geology in the northern part of southeastern Alaska* (20 minutes)
9. C. L. Hummel: *Structural geology and structural control of mineral deposits in an area near Nome, Alaska* (15 minutes)

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* Speaker

1:30 Paleontology

Room 100, Buchanan Building

Cochairmen: M. Y. Williams and R. L. Langenheim Jr.

1. Wayne L. Fry: *Early Tertiary flora from the Lower Fraser River valley, British Columbia* (15 minutes)
2. Jane Gray: *Tertiary pollen flora from the Basin and Range province, Arizona* (15 minutes)
3. W. P. Popenoe* and L. R. Saul: *Enigmatic Cretaceous pelecypod genus* Meekia (15 minutes)
4. Heinz A. Lowenstam: *O^{18}/O^{16} ratios and Sr and Mg contents in recent and fossil articulate brachiopods and their relationship to the water chemistry* (10 minutes)
5. Victor A. Zullo: *Eocene species of the genus* Balanus (*Cirripedia*) (10 minutes)
6. R. H. Waines: *Stromatoporoids of the Kennett limestone, Shasta County, California* (10 minutes)
7. J. Wyatt Durham: *Evolutionary trends in clypeasteroid echinoids* (15 minutes)
8. C. A. Nelson: *Stratigraphic range of* Ogygopsis (15 minutes)
9. Alan McGugan: *Upper Cretaceous Foraminifera from Vancouver Island, British Columbia, Canada* (15 minutes)
10. Orville L. Bandy: *Foraminiferal ecology of the Gulf of California* (20 minutes)

1:30 Mineralogy and Geochemistry

Room 102, Buchanan Building

Cochairmen: H. Warren and L. Staples

1. Ming-Shan Sun: *Differential thermal analysis of shattuckite* (10 minutes)
2. W. A. G. Bennett* and Gerald W. Thorsen: *Mode of deposition of ludwigite, kotoite, and cubanite in dunite on Jumbo Mountain, Snohomish County, Washington* (15 minutes)
3. A. Pabst* and Melvin C. Stinson: *Brannerite with gold from Plumas County, California* (10 minutes)
4. David B. Slemmons* and Terry E. Davis: *Relative speed and accuracy of some methods of measuring the position of optical directions by universal stage* (10 minutes)
5. Abraham Rosenzweig: *Optical and twin orientation of spurrite* (15 minutes)
6. D. B. Tatlock,* R. E. Wallace, and N. J. Silberling: *Alkali metasomatism, Humboldt Range, Nevada* (20 minutes)
7. Oreste W. Lombardi: *Distribution of the chemical elements in the salines of Saline Valley, Inyo County, California* (15 minutes)
8. F. W. Dickson, C. W. Blount,* and George Tunell: *Solubility of anhydrite in water from 100°C to 275°C and 1 bar to 1000 bars* (15 minutes)
9. F. W. Dickson,* D. L. Shields, and G. C. Kennedy: *Use of the temperature-gradient furnace to determine equilibrium sulfur pressures of metal-sulfide reactions* (10 minutes)

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1:30 Seismology

Room 104, Buchanan Building

Cochairmen: Maurice Ewing and John De Noyer

1. W. G. Milne* and K. A. Lucas: *Seismic activity in British Columbia*
2. William Stauder, S.J., *S waves: Alaska and other earthquakes*
3. D. E. Willis* and James T. Wilson: *Maximum vertical ground displacement of seismic waves generated by explosive blasts*
4. Jack G. Bouwkamp: *Behavior of window panels under lateral forces*
5. Jack Oliver: *Some observations of long-period seismic waves*
6. Don Tocher: *Two Hollister earthquakes*

SATURDAY MORNING

8:30 Northwest Petrology

Room 106, Buchanan Building

Cochairmen: J. Armstrong and P. Misch

1. Donald Carlisle: *Pillow breccias in the Vancouver volcanic rocks and their origin* (20 minutes)
2. A. C. Waters: *Twofold division of the Columbia River basalt* (20 minutes)
3. William R. Dickinson: *Petrology of Jurassic marine tuffs, central Oregon* (20 minutes)
4. Martin L. Stout: *Diabasic and gabbroic rocks in the south-central Cascade Mountains of Washington* (15 minutes)
5. Dwight L. Schmidt: *Pliocene silicic ignimbrites and basalt flows in the Bellevue quadrangle, Idaho* (10 minutes)
6. Arthur B. Ford: *Metamorphism and granitic intrusion in the Glacier Peak quadrangle, northern Cascade Mountains of Washington* (15 minutes)
7. Rowland W. Tabor: *Diaphthoritic gneiss in the Northern Cascades, Washington, and its structural significance* (20 minutes)
8. Robert J. Foster: *Precambrian corundum-bearing rocks in the Madison Range, southwestern Montana* (10 minutes)
9. Joseph A. Vance: *Origin of zoning in some igneous plagioclases* (15 minutes)

8:30 Seismology

Room 104, Buchanan Building

Cochairmen: Hugo Benioff and Jack Oliver

1. Joseph W. Berg, Jr., Kenneth L. Cook, and Harry D. Narans: *Seismic studies of crustal structure in the eastern Basin and Range province, Part II*
2. W. M. Adams, P. L. Flanders, W. R. Perret, R. G. Preston, and D. C. Sachs: *Ground-motion measurements on underground nuclear detonations*
3. John de Noyer: *Effect of variations in crustal thickness on Love-wave dispersion*

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* Speaker

4. Hugo Benioff: *Observations of the Lamb-Pekeris ground pattern in the Yellowstone earthquake of August 18, 1959*
5. Keiiti Aki: *Use of long-period surface waves for the study of earthquake mechanism*
6. Y. Sato, M. Landisman, and M. Ewing: *Love-wave dispersion in a heterogeneous spherical earth*
7. R. J. Brazee and Robert Gunst: *Hypocenter location of earthquakes by computer methods*

8:30 Stratigraphy

Room 100, Buchanan Building

Cochairmen: H. Wheeler and J. W. Durham

1. J. Keith Rigby: *Evidence for possible eustatic fluctuation in Permian sea level* (10 minutes)
2. R. L. Langenheim, Jr.,* B. W. Carss, J. B. Kennerly, V. A. McCutcheon, and R. W. Waines: *Paleozoic section in the Arrow Canyon Range, Clark County, Nevada* (15 minutes)
3. Harold J. Bissell: *Cordilleran fusulinid zonations* (20 minutes)
4. Vincent P. Gianella* and E. R. Larson: *Marine Permian at Black Rock, Nevada* (10 minutes)
5. Julian D. Barksdale: *Late Mesozoic sequences in the northeastern Cascade Mountains of Washington* (15 minutes)
6. C. H. Crickmay* and S. A. Pocock: *Upper Cretaceous of Vancouver* (20 minutes)
7. C. Carew McFall: *Geology of the Escalante-Boulder area, south-central Utah* (15 minutes)
8. Jack A. Wolfe: *Stratigraphy and paleobotany of the western Cascades of Oregon* (15 minutes)
9. Roald Fryxell: *Problems in glacial chronology of northern Washington* (15 minutes)
10. Charles F. Bacon: *New interpretation of relationships of Pliocene sediments to adjacent formations, Stanislaus County, California* (15 minutes)

8:30 Areal Geology

Room 102, Buchanan Building

Cochairmen: H. Sargent and C. Campbell

1. Peter B. Read: *Geology of the Fraser Valley from Hope to Emory Creek, British Columbia* (15 minutes)
2. A. C. Skerl: *Geology of the Texada iron mines, Texada Island, British Columbia* (20 minutes)
3. Wilbert R. Danner: *Revision of the geology of the San Juan Islands, Washington* (15 minutes)
4. Francis P. Shepard* and W. H. Mathews: *Underwater delta of Fraser River, British Columbia* (15 minutes)
5. William B. Bull: *Types of deposition on alluvial fans in western Fresno County, California* (15 minutes)
6. Charles M. Tschanz and Earl H. Pampeyan: *Geologic map of Lincoln County, Nevada* (15 minutes)
7. Marion T. Millett: *Advance of the Muldrow Glacier 1957* (20 minutes)

* Speaker

SATURDAY AFTERNOON

1:30 Symposium on Eugeosyncline of the Western Cordillera

Room 106, Buchanan Building

Cochairmen: V. Okulitch and W. H. Mathews

1. H. E. Wheeler: *Paleozoic-Mesozoic framework of the Cordilleran geosyncline* (25 minutes)
2. W. R. Danner: *Paleozoic eugeosynclinal sequence of southwestern British Columbia and northwestern Washington* (20 minutes)
3. A. Sutherland Brown: *Triassic and Jurassic rocks of the Queen Charlotte Islands* (20 minutes)
4. Edgar H. Bailey: *Franciscan formation of California as an example of eugeosynclinal deposition* (20 minutes)
5. Peter Misch: *West Cordillera metamorphic and granitic evolution* (25 minutes)

ABSTRACTS OF PAPERS SUBMITTED FOR THE MEETING IN VANCOUVER, BRITISH COLUMBIA, MAY 5–9, 1960

CORDILLERAN SECTION (GSA), PACIFIC COAST SECTION (PS), AND SEISMOLOGICAL SOCIETY OF AMERICA

GROUND-MOTION MEASUREMENTS ON UNDERGROUND NUCLEAR DETONATIONS

W. M. Adams, P. L. Flanders, W. R. Perret, R. G. Preston, and D. C. Sachs
University of California, Livermore, Calif.

Subsurface and surface-motion measurements were made on six underground nuclear detonations in the Oak Spring tuff at Nevada Test Site in Operation Hardtack II: shots Mars (13 tons), Tamalpais (72 tons), Neptune (90 tons), Logan (5 kt), Evans (55 tons), and Blanca (19 kt). Free-field peak radial accelerations decreased as the inverse third or fourth power of the slant range, as for the Rainier shot. Particle velocities attenuate at a rate between the inverse square and inverse cube. Maximum radial and tangential subsurface stress varied as the inverse cube of radial range. Observed peak strain suggests attenuation at a rate between inverse cube and inverse square of range. Maximum upheaval at Blanca surface zero was about 25.5 feet; at 750 feet it was 2.5 feet, and at 910 feet it was 1.5 feet. Reed gage spectra indicated a shift of maximum energy to lower frequency with increasing ground range. Vertical, radial, and transverse components of peak-surface acceleration followed an empirical equation of the form

$$A(g) = 3.2 \times 10^6 \, W^{0.7}(\mathrm{kt}) \, R^{-2}(\mathrm{ft}).$$

Components of peak-surface displacements followed individual relationships. Displacement is more precisely predicted than is acceleration. The tuff has a velocity of 6200 feet per second, the underlying dolomite 11,700 feet per second. The crust at NTS has a velocity of 6.58 km per second and a thickness of approximately 30 km. The top of the mantle has a velocity of 8.08 km per second and dips eastward.

USE OF LONG-PERIOD SURFACE WAVES FOR THE STUDY OF EARTHQUAKE MECHANISM

Keiiti Aki

Rayleigh and Love waves are used for the study of the earthquake mechanism by the method of phase equalization.

A comparative study of Love waves from California shocks with those from Nevada shocks strongly supports the hypothesis of a pair of couples for the earthquake source rather than a single couple.

Source motions of California shocks are derived from Rayleigh waves recorded at stations in the east by the equalization of phase delay caused by propagation and recording. It was found that the sense of the source motion thus derived is in agreement with the fault-plane solution obtained from the *P*-wave data.

Source motions of 53 circum-Pacific shocks are derived from Pasadena records of mantle Rayleigh waves. The shape of the source motion is interpreted, under reasonable assumptions, in terms of the direction of the force at the source. The direction of the force shows a systematic distribution which favors the hypothesis that right-hand strike slips prevail throughout the circum-Pacific earthquake belt.

GEOLOGY OF PROPOSED COLUMBIA RIVER DAM SITES, BRITISH COLUMBIA*

J. E. Armstrong
Geological Survey of Canada, B. C. Office, Vancouver, B.C.

Geological field examinations of 20 proposed dam sites were made. Most of the sites were drilled, and the holes logged by geologists. The geology of the 10 most important sites will be discussed briefly. The suitability of each site for dam abutments, spillways, and availability of materials will be referred to. Adverse geological conditions at some of the sites, which must be taken into account in future engineering and construction, will be described. The more important of these are: (1) buried river channels; (2) extensive faulting, shearing, and jointing; (3) slide areas; (4) abundance of schist; (5) abundance of limestone; (6) shortage of nearby materials for fill, aggregate, and riprap; and (7) thick deposits of permeable unconsolidated materials. Some sites have more adverse geological factors than others, and none has all those listed.

NEW INTERPRETATION OF RELATIONSHIPS OF PLIOCENE SEDIMENTS TO ADJACENT FORMATIONS, STANISLAUS COUNTY, CALIFORNIA

Charles F. Bacon
Sacramento, Calif.

Nonmarine lower and middle Pliocene rocks in Stanislaus County along the western edge of the San Joaquin Valley are exposed in a comparatively narrow belt extending from south of Tracy to a point near Newman, California. They rest in conformable and gradational contact upon the Neroly formation of Mio-Pliocene age and are unconformably overlain by nonmarine sediments considered equivalent to the Tulare formation of Plio-Pleistocene age.

The entire sequence of Pliocene and Pleistocene rocks above the Neroly formation has been questionably referred to the Tulare formation, but detailed mapping indicates that older Pliocene beds can be separated from the younger ones as follows: (1) dip variation often is in excess of 10° in the older beds, (2) lithologic variations only in the younger beds, (3) fossil evidence, (4) previous similar interpretation of an almost identical situation in an area separated to the south, and (5) older beds are missing to the north.

Studies of the two units with regard to engineering properties indicate that certain phases of the younger beds have lower slope-stability characteristics than any commonly found in the older beds and that the older beds are superior as a source of dependable borrow material. The younger unit contains more expanding clays than the older with the possible exception of reworked or residual material.

FRANCISCAN FORMATION OF CALIFORNIA AS AN EXAMPLE OF EUGEOSYNCLINAL DEPOSITION

Edgar H. Bailey
U. S. Geological Survey, Menlo Park, Calif.

Rocks assigned to the Franciscan formation range in age from Late Jurassic to Late Cretaceous and extend through the western part of California from the northern boundary southward for more than 500 miles to Santa Catalina Island. Its marginal position and the presence of serpentinites suggest that the eugeosyncline should be classed as ensimatic. The formation is at least 25,000 feet thick and may be much thicker. No lower contact has been recognized; what underlies it can only be inferred.

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* Published with permission of Director, Geological Survey of Canada

Rock types and estimated percentages are: graywacke (80), siltstone and shale (10), conglomerate (<1), limestone (<1), mafic volcanic rocks (8), chert and accompanying shale (<1), glaucophane and related schist (<1).

Graywacke is characterized by beds half an inch to tens of feet thick; absence of current or sorting features except in supposed lowest and highest parts; widespread shale fragments; local carbonized wood fragments; variable composition with feldspar $\frac{1}{3}$–$\frac{2}{3}$, quartz $\frac{1}{10}$–$\frac{1}{2}$, mafic volcanic rocks 0–$\frac{1}{3}$; matrix $\frac{1}{20}$–$\frac{1}{5}$, with finest fraction consisting of mica $>\frac{1}{3}$, kaolinite up to $\frac{1}{3}$, chlorite $<\frac{1}{3}$; highly angular to subangular grains; poor sorting.

Siltstone and shale, generally in thin interbeds with graywacke, are compositionally like the graywacke but finer-grained. Conglomerate is rare through the entire section. Beds are generally thin, but some are hundreds of feet thick. Clasts include both Franciscan and non-Franciscan types. Limestone, in thin beds of restricted distribution, is chemically precipitated and generally includes lenses of chert.

Mafic volcanic rocks are chiefly altered submarine eruptive rocks occurring as pillow lavas, breccias, and tuffs. Included are low-olivine basalt, spilite, and rarer quartz keratophyre. Chert, generally rhythmically bedded with distinctive iron-rich shale, is related spatially and probably genetically to volcanic rocks.

Most of the Franciscan formation is not metamorphosed; however, local areas contain laumontite, or jadeite, or glaucophane and associated minerals.

The rocks have been so folded, shattered, and sheared that nearly every outcrop presents some structural complexity, yet lithic units have mappable continuity. The gross structures seem to consist of open folds cut by strike-slip faults which nearly parallel fold axes. Major faults form wide zones containing blocks of competent rocks in a more highly sheared groundmass of less competent rocks.

SELECTIVE STAINING OF PLAGIOCLASE AND K FELDSPAR ON ROCK SLABS AND THIN SECTIONS

Edgar H. Bailey and Rollin E. Stevens
U. S. Geological Survey, Menlo Park, Calif.

Plagioclases, other than pure Na feldspar, may be stained an intense red after etching with hydrofluoric acid by dipping in barium-chloride solution, rinsing, and treating with a solution of potassium rhodizonate. Barium ion replaces calcium ion freed by etching the plagioclase and forms insoluble red barium rhodizonate.

Plagioclase can be stained red, and on the same surface K feldspar stained yellow by combining this procedure with the well-known cobaltinitrite method of staining K feldspar. If the K feldspar contains appreciable plagioclase, as in cryptoperthite, it is stained an intermediate orange color; coarser perthite may show individually stained lamellae.

Many applications of the technique are apparent. On stained slabs of granitic rocks the commonly obscure interrelations of the light-colored minerals—quartz and feldspars—are strikingly revealed, as are many fine details not otherwise readily observed. Modal analyses may be made more rapidly and probably more accurately on stained slabs or sections. The brilliant color contrasts make the stained slabs especially effective for student instruction.

FORAMINIFERAL ECOLOGY OF THE GULF OF CALIFORNIA

Orville L. Bandy
Department of Geology, University of Southern California, Los Angeles, Calif.

The Gulf of California is about 700 miles long, 100 miles wide, and more than 3000 m deep. Deep basins within the Gulf provide a highly diversified framework for the evaluation of biofacies patterns.

General faunal trends include the following: maximum species diversity and foraminiferal numbers occur on the outer shelf and upper slope; benthonic and planktonic Foraminifera are more abundant than diatoms and radiolarians on the continental shelf and in the upper bathyal zone; radiolarians and diatoms are most abundant in the sediments of basin bottoms; radiolarians are relatively more abundant than diatoms and Foraminifera in the deepest basins; porcellaneous Foraminifera constitute more than 20 per cent of the benthonic specimens of the inner shelf; malformed Foraminifera are most common in inshore waters; and dwarfism appears to be most common near the environmental limits of species.

Highly generalized dominant faunas are:

Environments	*Faunas* (Depths in meters)
Lagoonal	*Elphidium mexicanum* *Quinqueloculina* spp. *Streblus tepidus*
Beach	*Buccella tenerrima* *Cibicides fletcheri* *Elphidium crispum* Miliolids *Rotorbinella loamensis*
Inner Shelf	0–37 *Buccella mansfieldi* *Buliminella elegantissima* *Hanzawaia nitidula* *Nonionella basispinata*
Outer Shelf	37–152 *Bolivina interjuncta* *Bulimina denudata* *Cassidulina laevigata* *C. minuta* *Epistominella bradyana*
Upper Bathyal	152–610 *Bolivina plicata* *Bolivina seminuda* *Bulimina exilis tenuata* *Cassidulina delicata* *C. cushmani*
Upper Middle Bathyal	610–1524 *Bolivina argentea* *Bolivinita minuta* *Bulimina striata mexicana* *Epistominella smithi* *Pseudoeponides tener* *Valvulineria araucana*
Lower Middle Bathyal	1524–2438 *Eponides tumidulus* *Nonion barleeanus* *Uvigerina proboscidea* *Virgulina spinosa*
Lower Bathyal	Deeper than 2438 *Bulimina rostrata* *Nonion pompilioides* *Uvigerina senticosa*

LATE MESOZOIC SEQUENCES IN THE NORTHEASTERN CASCADE MOUNTAINS OF WASHINGTON

Julian D. Barksdale
Dept. Geology, University of Washington, Seattle, Wash.

Volcanic and sedimentary beds of the Upper Newby formation, northeastern Cascade Mountains of Washington, were previously assigned a "Triassic-Jurassic(?)" age. These strata have since been traced northward into marine beds of the same lithology containing fossils indicative of Neocomian (early Cretaceous) age.

A thick succession of marine plagioclase arkose, black siltstone, and shale and granitic boulder conglomerate rests with angular unconformity on the upper Newby. These beds which have an exposed thickness exceeding 10,000 feet are believed to be equivalent in part to the Ashcroft, British Columbia, Jackass Mountain "group" of probable Albian age.

The Virginian Ridge formation, dominantly black siltstone with intercalated chert grain sandstones and chert pebble conglomerates, is markedly discordant on the Newby and on the Jackass Mountain equivalent in some areas and disconformable on the latter in others. Its marine fossils have been variously dated as "Upper Albian-Cenomanian" or "Santonian-Campanian". The Winthrop arkose, conformable on the Virginian Ridge and only a few hundred feet thick in the Twisp River area, thickens to the north where it is correlated with "Division B and C" (14,000 $\pm$ feet) of the "Pasayten group" of Rice (1949). Conformable over the Winthrop is the red-bed Ventura formation of Russell (1898), equivalent in part to "Division D" of Rice's "Pasayten". The Ventura grades upward into the Midnight Peak andesitic sediments, breccias, and flows which may be equivalent in part to the Kingsvale "group".

Probable latest Cretaceous and/or earliest Tertiary deposition is represented by the Pipestone formation.

OBSERVATIONS OF THE LAMB-PEKERIS GROUND-RESPONSE PATTERN IN THE YELLOWSTONE EARTHQUAKE OF AUGUST 18, 1959

Hugo Benioff
Seismological Laboratory, California Institute of Technology, Pasadena, Calif.

Two seismograms of the Yellowstone earthquake of August 18, 1959, made with the Isabella fused-quartz extensometer exhibit very nearly the ground-response pattern first predicted by Lamb (1904) for an impulse source, as modified by Pekeris (1955) to correspond with a step source. In one of the seismograms the extensometer-output voltage which is proportional to ground strain was modified by a single-stage integrating network connected ahead of the recorder. This produced a response equivalent to a pendulum of 1000 seconds period. The other seismogram was recorded with a double-integrating network. Previous failures to record this pattern were due to insensitivity of existing instruments to the long-period waves involved relative to their response to the shorter-period vibratory movements of the ground resulting from the layered structure of the earth and the variation of wave speed with depth.

MODE OF DEPOSITION OF LUDWIGITE, KOTOITE, AND CUBANITE IN DUNITE ON JUMBO MOUNTAIN, SNOHOMISH COUNTY, WASHINGTON

W. A. G. Bennett and Gerald W. Thorsen
Washington Division of Mines and Geology, Olympia, Wash.

Rocks of early Tertiary age have been intruded by discontinuous sills or dikes of dunite, part of a belt of ultramafic intrusions that extends several miles southeastward to the Sultan Basin and the

Mackinaw mine. Both metasedimentary and ultramafic rocks were intruded by a quartz diorite stock from which boron-bearing fluids rose along small faults or shear zones, particularly in the dunite about 750 feet from the quartz diorite contact.

Introduction of boron and iron in at least two places, one 3000 feet northwest of Jumbo and the other 2000 feet south, under pneumatolytic conditions resulted in deposition, by replacement of the dunite, of considerable dark, blackish-green, silky, apparently iron-rich ludwigite (essentially opaque in the finest fibers). The kotoite, its precise location not yet determined, seems to have followed deposition of magnesium-rich ludwigite which in turn followed iron-rich ludwigite, indicating progressive impoverishment of iron locally in the gaseous emanations. In a few specimens ludwigite encloses magnetite, grains that probably are sulfides of nickel, and nickelian pyrrhotite.

Cubanite, which encloses other minerals not yet positively identified, is associated with chlorite (sheridanite) but not ludwigite and is apparently a few hundred feet nearer the quartz diorite contact than the two occurrences of ludwigite.

SEISMIC STUDIES OF CRUSTAL STRUCTURE IN THE EASTERN BASIN AND RANGE PROVINCE, PART II

Joseph W. Berg, Jr., Kenneth L. Cook, and Harry D. Narans
University of Utah, Salt Lake City, Utah

Results are presented from a continuation of the seismic studies of quarry blasts at Promontory and Lakeside, Utah.

Measurements were made of seismic energy at distances of 201.4 km and 243.7 km from a quarry blast at Lakeside, Utah, on February 8, 1959. Assuming the time–distance plot for the Promontory explosions (Berg and others, 1959) the energy traveling in the material characterized by a velocity of approximately 7.59 km/sec was first to arrive at these distances. The wave paths for the first arrivals passed beneath the Wasatch Mountains in the 7.59 km/sec medium for the station located at 201.4 km and beneath the Wasatch and Uinta mountains in the 7.59 km/sec medium for the station located at 243.7 km. After the data were corrected for elevations, observed delays were 0.11 second at 201.4 km for energy traveling beneath the Wasatch Mountains and 0.27 second for energy traveling beneath the Wasatch and Uinta mountains. Downwarpings of the surface of the 7.59 km/sec material were computed to be 1.3 km for the 0.11-second delay (probably within experimental error) and 3.1 km for the 0.27-second delay. More accurate velocity control for the elevation correction at 243.7 km could possibly change the time delay of 0.27 second.

A composite time–distance plot of seismic arrivals to a distance of approximately 1010 km from explosions at Promontory and Lakeside, Utah, shows that the first arrivals of seismic energy from these sources travel with velocities of 5.7 km/sec to a horizontal distance of approximately 80 km, 6.3 km/sec from 80 to 130 km, 7.6 km/sec from 130 to 630 km, and 8.0 km/sec from 630 to 1010 km. Assuming flat-lying beds and constant velocities, the data are interpreted to indicate three velocity discontinuities at depths of 9 km, 25 km, and 72 km, respectively. Additional data are needed to substantiate the existence of the 8.0 km/sec medium beneath the eastern Basin and Range province.

CORDILLERAN FUSULINID ZONATIONS

Harold J. Bissell
Brigham Young University, Provo, Utah

One-quarter century has elapsed since pioneer studies by Longwell and Dunbar in southern Nevada and by Thompson and Bissell in central Utah demonstrated utilitarian value of fusulinids in zonation of Pennsylvanian and Permian Cordilleran miogeosynclinal strata. Subsequent studies permit the present synthesis.

Strata of Late Chesteran age contain the Foraminifera *Endothyra*, *Paramillerella*, and locally

Millerella. Springeran rocks contain advanced species of these same genera. Morrowan strata have *Paramillerella* and *Millerella*, in association with *Nankinella* and *Pseudostaffella.* The genus *Profusulinella* typifies lower Derryan, and *Fusulinella* occurs in upper Derryan; *Eoschubertella* ranges throughout this series in some sections. The zone of *Fusulina* is valid for Desmoinesian rocks; *Wedekindellina* is found low in this series. *Triticites* characterizes Missourian rocks but does range through Virgilian and into Permian. *Kansanella* is found in upper Missourian. Virgilian strata contain advanced *Triticites* and *Waeringella.*

Rocks of Wolfcampian age are typified by presence of *Dunbarinella*, *Oketaella*, *Schwagerina*, *Pseudoschwagerina*, *Pseudofusulina*, and *Pseudofusulinella*; subzones contain certain genera only. *Bartramella* ranges from lower Desmoinesian into Wolfcampian. *Parafusulina* is abundant in Leonardian strata; advanced *Schwagerina* also occurs, and *Schubertella* can be found. Advanced forms of *Parafusulina* indicate presence of Guadalupean rocks; forms referred with query to *Leëlla* have been observed in Guadalupean series.

Subzones can be defined. Range zones have been established for numerous species. Spectacular success is achieved with rocks of Derryan and younger ages; some subzones contain certain genera, but most are defined by species having relatively wide distribution and limited stratigraphic range.

BEHAVIOR OF WINDOW PANELS UNDER LATERAL FORCES

Jack G. Bouwkamp
University of California, Berkeley, Calif.

The program reported in this paper was performed to investigate the ultimate in-plane deflection of fenestrated walls subjected to lateral forces.

Although it is apparently the intention of the California State Administrative Code, Section 111(b) of Title 21, to eliminate the possibility of glass breakage because of wind or seismic forces, no supporting test data were available.

Thirty-nine glazed window panels were tested under a horizontal in-plane racking force applied to the horizontal top member of a steel pin-connected, or hinged, loading frame, holding these panels. The following variables were included: panel size and panel configuration, panel attachment to hinged frame, sash material, clearance between glass and sash, and hardness of putty.

The ultimate in-plane deflections from head to sill under a racking load were determined theoretically for single-panel metal-sash windows glazed with soft as well as hard putty, and were in good agreement with the experimental results. Also for multiple-panel metal-sash windows glazed with soft putty, the calculated deflections were in good agreement with the test results.

HYPOCENTER LOCATION OF EARTHQUAKES BY COMPUTER METHODS

R. J. Brazee and Robt. Gunst
Coast and Geodetic Survey, Washington, D.C.

A method for locating hypocenters using an IBM 60 digital computer has been developed. In its most general form it is a simultaneous solution of equations of the form:

$$H + \frac{\partial T}{\partial \Delta} \cdot \frac{\partial \Delta}{\partial \lambda} + \frac{\partial T}{\partial \Delta} \cdot \frac{\partial \Delta}{\partial \phi} + \frac{\partial T}{\partial h} = A - C$$

where H is the origin time; A is the arrival time (recorded); and C is the arrival time (computed).

It was found that a very slight inaccuracy in the data and the vagaries of the average travel-time curves when applied to specific paths resulted in incorrect depth determinations. Therefore, various modifications have been made to permit the computer to discover and reject the data for extreme deviations and to allow it to test for depth by methods that depend on variations in epicentral distances to the several stations used in the computation.

TRIASSIC AND JURASSIC ROCKS OF THE QUEEN CHARLOTTE ISLANDS

A. Sutherland Brown
British Columbia Department of Mines, Victoria, B.C.

Triassic and Jurassic rocks of the Queen Charlotte Islands, British Columbia, are typical of those of the northern Pacific coast but are better preserved and exposed than in most areas. The oldest rocks are featureless greenstones more than 6000 feet thick, overlain conformably by Karnian and Norian marine sedimentary rocks. The latter consist of massive gray clastic limestone 200 to 650 feet thick, overlain by 400 to 800 feet of thin-bedded black limestone, and in turn overlain by about 1900 feet of thin-bedded black limy argillite and argillaceous limestone. The Triassic rocks were folded and beveled prior to the deposition of 2000 to 3000 feet of Toarcian conglomerates, brownish graywackes, and gray shales. These lower Jurassic rocks have been called the Maude formation on Skidegate Inlet. Overlying the Maude is a volcanic sequence characterized by fragmental rocks. Of three intergrading facies, one is composed of andesitic pillow lavas and aphanitic fragment agglomerates and is 7000 to 10,000 feet thick, another of ignimbrites at least 5000 feet thick, and a third of porphyry fragment agglomerate, andesite porphyry flows, and volcanic sedimentary rocks 7000 feet thick. Rocks of the latter facies on Skidegate Inlet have been called the Yakoun formation and range in age from Bajocian to Callovian.

TYPES OF DEPOSITION ON ALLUVIAL FANS IN WESTERN FRESNO COUNTY, CALIFORNIA

William B. Bull
U. S. Geological Survey, Sacramento, Calif.

Deposition on alluvial fans in western Fresno County is caused by widening of a flow as it spreads out on the fan. The widening is accompanied by a decrease in depth and velocity, thus causing sediment to be deposited.

The deposits may be mudflows, water-laid sediments, or a type intermediate between mudflow and water-laid sediments. Depositional characteristics and grain-size analyses of 102 samples provide some defining properties for these three general classifications. Only 12 of the 277 sorting indices are outside the limits set for the depositional types. The three sorting indices used were the Trask sorting index, *So*; the quartile deviation, $QD\phi$; and the standard deviation, $\sigma\phi$.

Most of the samples contain shale fragments and a montmorillonite-type clay, in addition to quartz, feldspar, and other rock and mineral fragments. The quantitative properties listed in the table may be different for deposits that have different source rocks.

Water-Laid Sediments	Intermediate Deposits	Mudflow Deposits
	Depositional Characteristics	
No discernible margins; usually clean sand or silt; cross-bedded, laminated, or massive	No sharply defined margins; clay films around sand grains and lining voids; graded bedding and oriented fragments	Abrupt, well-defined margins, lobate tongues; clay may partly fill intergranular voids. May not have graded bedding or particle orientation
	Average Parameters from Grain-Size Analyses	
Clay content is 6 per cent, *So* is 1.8, $QD\phi$ is 0.8, $\sigma\phi$ is 1.4.	Clay content is 17 per cent, *So* is 4.0, $QD\phi$ is 2.0, $\sigma\phi$ is 3.9.	Clay content is 31 per cent, *So* is 9.7, $QD\phi$ is 3.1, $\sigma\phi$ is 4.7.

PILLOW BRECCIAS IN THE VANCOUVER VOLCANIC ROCKS AND THEIR ORIGIN

Donald Carlisle
Department of Geology, University of California, Los Angeles, Calif.

Isolated-pillow breccias and broken-pillow breccias on Quadra Island, British Columbia, are neither flow breccias nor pyroclastic rocks in the usual sense, but have characteristics both of turbidites and of ignimbrites.

In several typical successions ordinary close-packed pillows at the base rest upon basalt flows or upon bedded limestone. Matrix between pillows is less than 10 per cent of the rock. Gradationally upward the matrix increases to as much as 80 per cent, the pillows become isolated and diversiform, and small pillows become common. Some pillows are split. The matrix, mainly palagonitic crystal tuff with basaltic fragments, has a foliation resembling compact structure in ignimbrites. Above this in gradational contact is nonstratified breccia with similar matrix but with fragments of pillows broken after solidification. The proportion of broken pillows and of small clasts increases upward. Laminated tuff with load casts in its upper surface occurs within the broken-pillow breccia.

Close-packed pillows apparently accumulated in relatively clear water and reached their present position while plastic. Isolated pillows were buoyed up by increasingly turbid and vapor-charged water as tuffaceous debris, partly spalled from pillows partly pyroclastic, accumulated. Thickening of the water-pillow-tuff mass led to instability, subaqueous slumping, and fragmentation of solidified pillows.

Pillow breccias of this origin may occur more generally than has been realized. Similar rocks have been described from at least five localities elsewhere in the world. Others closely resembling isolated-pillow breccias have been called flow-top breccias.

ROCKFILL DAMS

Allen S. Cary
U.S. Army Engineers, Marginal Way, Seattle, Wash.

For the purpose of this discussion rockfill dams are defined as dumped and sluiced rock fill with slopes at approximately the angle of repose of the rock. The downstream slope is generally left as dumped and sluiced. The upstream slope is generally covered with impervious material with proper bedding and cover or filters, and the face which will be exposed to the reservoir is blanketed with rocks for stability and prevention of wave cutting.

Difficulties encountered during construction of certain rockfill dams in the States indicate that physical properties of the rock available for the fill have not been given enough consideration. The young science of Rock Mechanics has grown up in the mining and tunneling industry and has direct application to rockfill dam design, very much simplified and still an art, but applicable none the less. The most important physical properties of rock and tentative recommended values are as follows:

Compressive strength	Minimum	7500 psi
Absorption	Maximum	3 per cent
Specific gravity (Apparent)	Minimum	2.55
Seismic velocity	Minimum	5000 to 7500
Freeze–thaw test	Maximum	
	Loss 50 cycles	1.5 per cent
	Loss 100 cycles	5.0 per cent

If values of rock from a specific job approach these values, very serious study is indicated. The height of dam and allowable dumping height will be important if the available rock has compressive strength less than 10,000 psi.

EARTHQUAKE RECORDED BY LOW-COST INSTRUMENT

William K. Cloud
Coast and Geodetic Survey, San Francisco, Calif.

As part of a current project to supplement the Coast and Geodetic Survey strong-motion seismograph network with low-cost instruments, the Survey seismoscopes were installed at Hollister, California, at the Almaden Winery on the San Andreas fault, and at the Westvaco Quarry west of the fault. The first sizable records were obtained from a magnitude 5 earthquake on January 19, 1960. Results are given in terms of maximum velocity obtained by the seismoscopes and are compared with the velocity spectrum computed from the Hollister accelerograph record.

RELATIONS OF MAJOR FOLDS AND REVERSE FAULTS IN SANTA LUCIA RANGE, CALIFORNIA

Robert R. Compton
Department of Geology, Stanford University, Stanford, Calif.

Major Plio-Pleistocene folds and faults of the California Coast Ranges are displayed unusually clearly in the rugged country of Junipero Serra quadrangle. The area is significant because granitic and metamorphic rocks that here form the core of Santa Lucia Range were pressed into large anticlines and synclines before they rose vertically along high-angle reverse faults that cut these folds. The basement was folded so severely that its upper surface dips more than 45° in many places. The faults are spaced at intervals of half a mile to 3 miles and typically dip 60°–85° toward former anticlines. Thick sequences of Tertiary strata are preserved in major synclines that lie along the border of the basement core and are commonly overturned away from it. These sedimentary remnants indicate that the basement was overlain by 5000–15,000 feet of beds when folding started.

The core consists of a central granitic mass and a mantle of high-grade metamorphic rocks. Although these rocks are crushed here and there, their textures are deformed moderately if at all. Judged from a common parallelism between metamorphic foliations and the Plio-Pleistocene faults, the metamorphic structures may have guided the later deformations to a considerable degree. The close association of horizontal folds and steep reverse faults (rather than thrusts and tear faults) was possibly caused by a compression that acted on the intermediate part of the crust as well as on its upper part.

GEOLOGIC PROBLEMS AT THE GORGE HIGH DAM, SKAGIT RIVER, WASHINGTON

Howard A. Coombs and C. R. Hoidal
University of Washington, Seattle, Wash.

Seattle City Light's Gorge High dam is located in the northern Cascades approximately 22 miles south of the Canadian border. At the site the river flowed parallel to and on a bedrock ridge separating deep buried channels on either side. The fill was composed predominantly of sand but contained lenses of gravel and scattered blocks and boulders.

Adverse geological features included artesian water issuing from drill holes in the gneissic bedrock ridge, a fault at the base of the right abutment, and loose joints in the near-vertical canyon walls above the deep excavation. The presence of a diversion dam 400 feet upstream from the site caused a high head for ground water close to zone of deep excavation. The limited space between the new and existing dam required upstream excavation slopes to be 1½:1 or steeper to provide room for diversion facilities. The safety of the existing dam providing 108,000 kw had to be insured.

The unique solution to this problem was a frozen, subsurface dam with a maximum height, in the left channel, of 220 feet. Brine was pumped through vertical drill holes spaced at 4 feet on centers.

Temperatures throughout the freeze curtain were measured by thermocouples. The freeze curtain has proved to be an effective cofferdam. The faulting was treated by cleaning and backfilling and a slight design change. The loosely jointed rocks were stabilized by pinning.

UPPER CRETACEOUS OF VANCOUVER, BRITISH COLUMBIA

C. H. Crickmay and S. A. Pocock

Sections of the Cretaceous system in Comox and Nanaimo areas, British Columbia, are reviewed and correlated. Correlations are carried, with the aid of plant megafossils and microfloral evidence, to several mainland areas, particularly the vicinity of the city of Vancouver. It is shown that the Capilano Creek beds and equivalents on the mainland are correlative with the lower formations of the Nanaimo series, whereas the Stanley Park and the Barnett beds are correlative with the upper formations at Nanaimo. Although long suspected, the older interpretations, with which these new conclusions are at variance, are now controverted mainly with the aid of detailed, quantitative microfloral evidence. Conclusions are that the Upper Cretaceous basin was of great breadth, extending widely over Vancouver Island and the Straits and thence eastward into what is now the Cascade Range. Various evidence is used to date the orogeny which finally disintegrated the Cretaceous basin.

PALEOZOIC EUGEOSYNCLINAL SEQUENCE OF SOUTHWESTERN BRITISH COLUMBIA AND NORTHWESTERN WASHINGTON

Wilbert R. Danner
University of British Columbia, Vancouver, B.C.

Adjacent parts of southwestern British Columbia and northwestern Washington contain the only definitely identified Paleozoic rocks exposed along the Pacific Coast of North America between the Klamath Mountains of southwestern Oregon and the Alaska Panhandle. Units known to occur have ages including Middle Devonian, Early and Middle Pennsylvanian, Early Permian, and Middle and Late Permian. Rocks of the eugeosynclinal suite characterize the sequence.

The Middle Devonian consists of at least 1400 feet of spilitic volcanic rocks, graywacke, graywacke siltstone, argillite, breccia, conglomerate, ribbon chert, and reef-complex limestone. In the San Juan Islands these rocks appear to rest unconformably on an amphibolitic gneiss complex cut by dioritic rocks. The Lower and Middle Pennsylvanian consists of more than 3000 feet of argillite, shale, graywacke, volcanic rocks, chert, and limestone. It is geographically the most widespread sequence. Disconformably above the Pennsylvanian in several areas is 100–600+ feet of conglomerate and plant-bearing carbonaceous sandstone believed to represent continental deposition. At one locality this is overlain by Lower Permian limestone. The Lower Permian consists of at least 1000 feet of chert, graywacke, volcanic rocks, and fusulinid limestone. Middle and Upper Permian rocks include ribbon chert and volcanic rocks containing limestone lenses, breccias, argillite, and graywacke. The thickness is thought to be at least 10,000 feet. The limestone members contain a Tethyan fusulinid and algal fauna similar to that of the upper part of the Cache Creek group of interior British Columbia.

REVISION OF THE GEOLOGY OF THE SAN JUAN ISLANDS, WASHINGTON

Wilbert R. Danner
University of British Columbia, Vancouver, B.C.

Recent studies of the geology of the San Juan Islands in northwestern Washington have necessitated the revision of at least four major units established by the pioneer work of McLellan in 1927.

The Orcas group, originally designated as Devono-Mississippian, is now known to contain rocks of Middle Devonian, Early and Middle Pennsylvanian, Middle and Late Permian, and Late Triassic age. No diagnostic Mississippian fossils have been found. The Leech River group, originally designated as Pennsylvanian–Permian, was found to include rocks of Early and Middle Pennsylvanian and Cretaceous age. Volcanic rocks originally described as intrusive dikes of the Eagle Cliff porphyrite appear to be composed largely of submarine pillow lavas of Permian and Cretaceous age. The Turtleback complex described as a variety of intrusive rocks, offshoots of a late Jurassic batholith located to the west on Vancouver Island, is now known to include many areas of an amphibolite gneiss complex intruded by dioritic rocks of pre-Devonian age. Granitic rocks thought to be of early Mesozoic or later age are also present. In addition the Turtleback contains volcanic and sedimentary rocks of Devonian, Early Permian, and Middle and Late Permian age. Large areas on the Islands contain sequences as yet unassigned to a definite place in the geological column.

EFFECT OF VARIATIONS IN CRUSTAL THICKNESS ON LOVE-WAVE DISPERSION

John De Noyer
Dept. Geology, University of Michigan, Ann Arbor, Mich.

Crustal structures obtained from Love-wave dispersion yield "average" thicknesses along the propagation paths. The validity of these results depends on the crust being uniform in thickness along the propagation paths. In many cases there are at least portions of the path in which this condition is not satisfied. An evaluation of the effect of thickness variations on both the group and phase velocities can be obtained by considering a crust whose thickness varies as a sine function of distance. The effect of any portion of a sinusoidal thickness variation can be considered. This provides a method for evaluating the effect of even rapid thickness variations as long as they can be approximated by a sine curve.

PETROLOGY OF JURASSIC MARINE TUFFS, CENTRAL OREGON

William R. Dickinson
School of Mineral Sciences, Stanford University, Stanford, Calif.

Near Izee on South Fork of John Day River in Grant County, Oregon, approximately 17,500 feet of marine Jurassic sedimentary and pyroclastic strata is exposed in a steeply dipping homoclinal sequence. Original plagioclase in most beds has been partially or completely converted to epigenetic albite. Three homogeneous tuff units that display varying degrees of albitization and related alteration along their strike were studied by field and petrographic examinations, and 25 chemical analyses were made of samples collected from them.

In an acidic vitric-crystal tuff unit, albitization resulted from pronounced soda metasomatism accompanied by slight increase in silica, decrease in iron, strong dehydration, and drastic reduction in CaO, MgO, and K_2O. Least altered rock is composed dominantly of zeolitized shards with optics suitable for heulandite. Metasomatism converted most of this rock to microcrystalline albite and quartz. Field relationships suggest that connate waters driven from associated marine mudstones by compaction appear to be the only feasible source of soda-rich fluids.

In two andesitic lithic-crystal tuffs, partial or complete albitization of plagioclase was not accompanied by significant changes in chemical composition, nor was clinopyroxene altered. Hydrous lime-rich alteration products occur as tiny inclusions (pumpellyite?) in albite and as microcrystalline aggregates (prehnite?) forming a discontinuous network interstitial to clastic grains. The patchy pattern of alteration, even on a microscopic scale, suggests that local availability of interstitial water for reaction and catalysis controlled its progress, although the underlying impulse was doubtless metastability of calcic plagioclase.

SOLUBILITY OF ANHYDRITE IN WATER FROM 100°C. TO 275°C. AND 1 BAR TO 1000 BARS

F. W. Dickson, C. W. Blount, and George Tunell
Dept. Geology and Institute of Geophysics, University of California, Riverside, Calif.; Dept. Geology and Institute of Geophysics, University of California, Riverside, Calif.; Dept. Geology, University of California, Los Angeles, Calif.

The solubility of anhydrite in water was determined from 100°C. to 275°C. and from 1 bar to 1000 bars with specially designed hydrothermal-solution equipment. A stainless-steel pressure vessel encloses a chemically inert variable-volume tetrafluorethane (Teflon) cell from which an internally filtered liquid sample can be withdrawn with negligible disturbance of equilibrium conditions. Experimental mixtures were stirred by action of a Teflon-coated bar magnet turned by an externally applied pulsating magnetic field. Equilibrium was attained in 48 hours or less. $CaSO_4$ percentages were determined to better than ± 1 per cent of the value reported.

Anhydrite solubility decreases with increasing temperature and increases with increasing pressure. At 100 bars and 100°C., weight per cent $CaSO_4$ is 0.085; at 100 bars and 275°C., 0.0015. At 100°C. and 1 bar, weight per cent $CaSO_4$ is 0.074; at 100°C. and 1000 bars, 0.210. Our solubilities measured at the vapor pressure of the system agree closely with data of other workers.

Geologic conclusions are: (1) anhydrite will not precipitate from initially saturated solutions migrating toward the earth's surface in fissures in rocks possessing a "normal" geothermal gradient because the increase in solubility caused by decreasing temperatures more than compensates for the decrease in solubility caused by decreasing pressure; and (2) anhydrite would precipitate from saturated solutions moving from high to low pressure at constant temperature, as would be the case in and near fissures toward which a fluid-pressure gradient exists.

USE OF THE TEMPERATURE-GRADIENT FURNACE TO DETERMINE EQUILIBRIUM SULFUR PRESSURES OF METAL SULFIDE REACTIONS

F. W. Dickson, D. L. Shields, and G. C. Kennedy
Dept. Geology and Institute of Geophysics, University of California, Riverside, Calif.; Dept. Chemistry, University of California, Los Angeles, Calif.; Institute of Geophysics, University of California, Los Angeles, Calif.

Sulfur pressures of univariant metal sulfide-sulfur gas equilibria, of the form $MS_2 \rightleftharpoons MS + S_{(gas)}$, are of considerable interest in problems of sulfide mineral genesis. However, sulfur-pressure measurement at high temperatures is difficult because sulfur reacts with most laboratory materials. A rapid and convenient new method has been devised to measure sulfur pressures by a dew-point technique which utilizes a furnace designed to establish a zone of constant temperature at one end of the furnace and a controlled temperature gradient along the rest. Temperatures are measured by thermocouples positioned along the furnace core. Metal sulfides and sulfur gas are equilibrated at constant temperature at one end of a sealed evacuated glass tube, the other end of which is a capillary along which a falling temperature gradient has been established. Sulfur liquid condenses in the cooler portions of the capillary, creating an interface between liquid and gas where the temperature is such that liquid and gaseous sulfur can coexist at the pressure of the system. From the temperature at the interface the sulfur pressure can be evaluated from known sulfur vapor pressure data. Sulfur pressures thus determined together with sample temperatures determine points on the sulfur pressure versus temperature curve representing the univariant equilibrium. Data on systems Cu-S and Fe-S determined by this method agree well with data of previous workers. The method is of general use for studies of multi-phase equilibria which involve gases for which vapor-pressure data are known.

EVOLUTIONARY TRENDS IN CLYPEASTEROID ECHINOIDS

J. Wyatt Durham
University of California, Berkeley, Calif.

The holectypoid ancestor of the clypeasteroid echinoids had no food grooves, possessed continuous interambulacra that were much wider than the ambulacra, and the periproct was marginal, distant 8 to 10 pairs of postbasicoronal plates from the peristome.

Among the clypeasteroids these characters evolved independently of one another. The earliest recorded members of the group, from the Maestrichtian of the Old World, assigned to the genera *Echinocyamus* and *Fibularia* lack food grooves, have narrow continuous interambulacra on the oral surface, and have the periproct near the peristome. Because of the position of the periproct as well as other specialized characters these Cretaceous species cannot be ancestral to most geologically younger clypeasteroids. The suborder Laganina to which these echinoids belong is in part characterized by continuous narrow interambulacra; by simple, unbranched food grooves or none; and usually by an advanced position of the periproct. The suborder Clypeasterina, with its earliest recorded members in the Eocene, is in part characterized by orally discontinuous interambulacra; simple unbranched food grooves; and a periproct near the ambitus. The suborder Scutellina, first recorded from lower Eocene, is in part characterized by periproct variable in position; interambulacra mostly continuous in early members and discontinuous later; and food grooves that tend to become complex. The suborder Rotulina is enigmatic, comparing with the scutellinids in character of the interambulacra and food grooves but more closely related to the laganinids by position of the periproct and features around the apical system.

MODAL VARIATIONS WITHIN AN OUTCROP OF THE SAGEHEN ADAMELLITE

D. O. Emerson
Department of Geological Sciences, University of California, Davis, Calif.

Stable estimates of modal parameters can be obtained only after the sampling problem has been solved. To aid in solving this problem, the source and magnitude of modal variation within an outcrop was determined for an adamellite of the Northern Inyo Range, California.

Three levels of variation within an outcrop (traverses within sections, sections within hand samples, hand samples within outcrops) were studied. This adamellite is equigranular with an average grain size of 2 mm and an I.C. number of 50. The modes were determined by micro point counting. Sixteen traverses of 100 points each were made on 4 thin sections from each of 4 hand samples.

As shown by the chi-square index of dispersion, the traverses within sections were generally not random samples of a homogeneous population. However, nonsignificant probabilities were found for the heterogeneity chi-square of the major minerals. Using the nested-samples model of the analysis of variance, no significant differences between duplicate counts of a thin section were found at the 99 per cent level. The "mafics" yielded significant differences among thin sections from the same sample. This is probably due to their arrangement in the sample. Modal quartz differs significantly among hand samples.

These variations show that, for efficient sampling, either a separate plan is required for each mineral or an adequate compromise must be determined by an initial study of each problem.

DIABASE–GRANOPHYRE RELATIONS IN THE ENDION SILL, DULUTH, MINNESOTA

W. G. Ernst
Department of Geology, University of California, Los Angeles, Calif.

The gently dipping 1500-foot thick Endion sill intrudes Keweenawan flows at Duluth, Minnesota. From the bottom to the top of the body, there is a gradual transition from diabase (60 per cent of exposed mass) through intermediate rock (granodiorite) to granophyre (adamellite). Fractional

crystallization of basaltic magma produced a great thickness of basic and intermediate rock types which accumulated predominately in the lower portions of the sill, and probably in the end stage of an aqueous, salic, alkalic liquid. It is proposed that, owing to initial inclination of the sill, part of this salic fraction migrated up dip, accumulated and reacted with portions of the diabase and intermediate rock, and completed crystallization at the presently exposed level. Alternatively, much or all of the Endion sill granophyre may represent a separate unrelated intrusion. In either case the sill is composite. Bulk compositions of cryptoperthites indicate that both granophyre and intermediate rock crystallized at magmatic temperatures.

Compositional uniformity of the clinopyroxene and lack of iron enrichment in felsic portions of the Endion sill may be the result of accumulation of H_2O and the presumed maintenance of nearly constant partial oxygen pressure during crystallization. This mechanism would furthermore account for inferred late magmatic solid solution between alkali feldspar and $KFe^{+++}Si_3O_8$, with subsequent subsolidus exsolution of hematite.

METAMORPHISM AND GRANITIC INTRUSION IN THE GLACIER PEAK QUADRANGLE, NORTHERN CASCADE MOUNTAINS OF WASHINGTON

Arthur B. Ford
Dept. Geology, San Diego State College, San Diego, Calif.

A northwest-trending series of regionally metamorphosed rocks includes a lower thick unit of pelitic schists with subordinate amphibolites and granulites, and a higher unit of granitic gneisses with local intercalations of amphibolite and hornblendite. Typical migmatites locally predominate.

Original geosynclinal shales, if pure, formed mica schists commonly with kyanite or staurolite or, if impure, formed calc-mica schists or hornblende-mica schists. With increase of original impurities mica schists grade into para-amphibolites. Tuffaceous sandstone or slightly argillaceous dolomitic sandstone formed quartzitic hornblende granulite and garbenschiefer. Basic volcanic rocks became orthoamphibolites. Pure limestones and quartz sandstones were rare.

Progressive metamorphism was synkinematic, at least in early stages. Postkinematic recrystallization weakened earlier schistosity; in some isochemical rocks this produced granulites and garbenschiefer, and, where accompanied or preceded by alkali and silica introduction, weakly gneissose to directionless quartz dioritic to granodioritic rocks resulted. In general, highest grade attained was kyanite zone. Retrogression was minor and local.

Quartz dioritic and related magmatic rocks were discordantly emplaced in the vicinity of Miners Ridge. Autometamorphism resulted in crystalloblastic textures, clearly superimposed upon *earlier* typically igneous features in many rocks. Where present, epidote has formed at expense of plagioclase or hornblende.

Although megascopically similar, older metamorphic granitoid rocks are distinguished from younger igneous ones by having: (1) early crystalloblastic features, locally with superimposed general, weak cataclasis which suggests mobilization; (2) abundant idioblastic (contemporaneous) epidote; (3) gradational contacts, through wide zones of migmatites, with adjacent schists; (4) numerous inclusions (skialiths, etc.) aligned with country-rock structures.

PRECAMBRIAN CORUNDUM-BEARING ROCKS IN THE MADISON RANGE, SOUTHWESTERN MONTANA

Robert J. Foster
Montana State College, Bozeman, Mont.

The corundum-bearing rocks occur with Precambrian gneiss, schist, amphibolite, quartzite, and minor iron formation and were considered igneous by Heinrich (1949; 1950) and metasedimentary by Clabaugh (1952). At three places feldspathic gneiss, composed of alkali feldspar and biotite with accessory rutile and skeletal corundum, contains up to 10 per cent large corundum crystals sur-

rounded by alkali feldspar halos. These rocks parallel the regional foliation and grade laterally into rocks composed entirely of sillimanite and muscovite. Apparently high-grade metamorphism of an aluminous sediment produced syenite gneiss; next, perhaps in this phase (Clabaugh, 1952) unoriented corundum ovoids formed by replacement of the gneiss with addition of aluminum and potassium. The final step was local development of sillimanite-muscovite rocks. Hornblendite and amphibolite occur at each of the three corundum localities. Relict pyroxene in amphibolite and other evidence suggest granulite-facies metamorphism followed by amphibolite-facies metamorphism. Reid (1957) noted similar evidence and conclusions in the Tobacco Root Mountains immediately west. The gneiss and ovoids probably formed during the granulite (?)-facies metamorphism which Reid believes was accompanied by feldspathization. Sillimanite and muscovite probably developed during the amphibolitic metamorphism, and there is some evidence of feldspathization of the amphibolites.

Zircon studies suggest a sedimentary origin, but trace-element content does not support a bauxite origin. Nearby iron formation suggests that the aluminous sediment may represent prolonged weathering and may be a significant mappable zone. In other areas corundum is associated with ultrabasic intrusive rocks, but variable composition of the hornblendite and amphibolite suggests that they are para-amphibolites.

EARLY TERTIARY FLORA FROM THE LOWER FRASER RIVER VALLEY, BRITISH COLUMBIA

Wayne L. Fry
Department of Paleontology, University of California, Berkeley, Calif.

Outcroppings of continental sediments in the lower reaches of the Fraser River valley have yielded numerous fossil land plants. The sediments from which the specimens were collected have been mapped as the Burrard, Kitsilano, and Huntingdon formations. Earlier investigators considered the flora of the Burrard as Eocene, whereas some considered the Kitsilano to be Oligocene. The flora as now known contains about 60 species. Among the genera are *Macclintockia* and *Lygodium*. The flora shows remarkable uniformity and contemporaneity, and the plants suggest a Middle Eocene age for the formations. The plants indicate a warm to subtropical climate characteristic of this part of the Tertiary. Microfossil evidence based on pollen supports these opinions.

PROBLEMS IN GLACIAL CHRONOLOGY OF NORTHERN WASHINGTON

Roald Fryxell
Dept. Geology, Washington State University, Pullman, Wash.

Studies of continental glaciation in northern Washington have utilized a variety of criteria for establishing the age of various episodes. Depending on the availability of field evidence, different workers have used stratigraphy, weathering, erosion, physiographic expression, rate of talus accumulation, relationship to units in the Palouse loess, bedrock topography, and radiocarbon analysis. Weathering, topographic expression, and radiocarbon dating support correlation of the last major glacial advance as Wisconsin. However, substage correlations result in major inconsistencies:

(1) The last advance in Puget Sound has been referred to Tazewell (13,700 BP), while its apparently equally weathered and supposedly synchronous counterpart across the Cascades, the Okanogan lobe, has been designated Mankato (10,000 BP?);

(2) Restricted valley glaciers a few hundred feet thick, sharing the catchment divide in southern British Columbia of the mile-thick Okanogan lobe, have also been dated as Mankato (post 11,300 BP);

(3) The Spokane lobe has been suggested to be early or pre-Wisconsin although north of its terminus it merged with the Okanogan lobe;

(4) East of Grand Coulee the stratigraphic evidence available in Puget Sound and Cascade areas is almost lacking, and nearly every ice margin so far suggested has been disputed; little agreement exists here or in northern Idaho as to whether recognizable moraines are terminal or recessional.

Until the precise relationship of ice advances within northern Washington itself can be established,

correlation at the substage level with Midwestern chronology cannot be satisfactory. Present attempts fail because of insufficient field work, lack of stratigraphic information, and scarcity of radiocarbon dates.

FAULTING IN NORTHEASTERN SONORA, MEXICO, IN 1887

Vincent P. Gianella
University of Nevada, Reno, Nev.

Faulting associated with the Sonora, Mexico, earthquake of May 3, 1887, extends farther than previous mapping indicates, particularly south of the Bavispe River. This earthquake rates among the strongest experienced in the western United States.

The fault extends southerly from a few miles south of the Mexico–United States boundary for about 50 miles.

Right-lateral movement of up to 20 feet displaces andesites and leaves scarps up to 20 feet high. Near this place, a few miles north of where the fault crosses the Bavispe River, are several sharp bends, approaching right angles, with intervening, nearly straight segments several thousand feet in length. These bends have a short radius of curvature. Twenty miles to the north scarps up to 21 feet were measured.

Displacement is negligible where the fault crosses the Bavispe River, but the scarp increases to a height of many feet farther south. South of the river the recent scarp appears to follow an ancient line of faulting along the western slope of the Teras Range (Sierra de la Madera) and has been traced for 12 miles south of the Bavispe through the Cinco de Mayo mining district and beyond.

MARINE PERMIAN AT BLACK ROCK, NEVADA

Vincent P. Gianella and E. R. Larson
University of Nevada, Reno, Nev.

Black Rock, a prominent topographic feature of the Black Rock Desert in northwest Nevada, was first reported by John C. Fremont who, in 1844, noted the abundance of black fragments, like the cinders from a blacksmith's forge, at the base of this sharply conical hill.

The rock, generally thought to be a mass of volcanic-flow rock, received only cursory attention over the years. Recent detailed examination has shown the cone to be composed of very steeply dipping, fossiliferous, volcanic sediments and limestones. The fossiliferous beds contain well-preserved upper (?) Permian brachiopods. This is the westernmost exposure of fossiliferous Permian strata known in the State.

The Black Rock Permian consists of more than 1800 feet of volcanic sediments with variable amounts of limestone and includes a 100-foot unit of well-bedded limestone. The major portion of the sequence is 1- to 2-foot beds of andesite clasts which average about half an inch in diameter but range from a small fraction of an inch to 6 inches. The volcanic rocks consist principally of augite andesite breccia.

The volcanic sediments at Black Rock are typical of accumulations in eugeosynclines. In these belts local volcanic sources may supply volcanic detritus to adjacent areas of limestone deposition. In some fortuitous circumstances, as at Black Rock, organic remains are preserved in the more limey beds and in the dominantly volcanic detritus.

TERTIARY POLLEN FLORA FROM THE BASIN AND RANGE PROVINCE, ARIZONA

Jane Gray
Geochronology Laboratories, University of Arizona, Tucson, Ariz.

A newly discovered microflora provides the most detailed record of Arizona Tertiary vegetation. The fossils come from tuffs near 5600 feet in the mountains 4 miles northwest of Prescott. The tuffs are tentatively referred to the Clarendonian on the basis of the regional geology and paleontology.

Most abundant are the arborescent oak, juniper, cupressus, and pine (of the pinyon type). These are the characteristic genera of brushland and woodland communities of central and southeastern Arizona today. Among nonarborescent plants, grasses, composites (including sagebrush, Ambrosieae, and others), and chenopod-amaranths are common. Except for elm, the identified genera and families (*ca.* 80 per cent of the flora) live nearby, and all are represented by pollen in recent sediments near Prescott.

The fossil flora approximates the vegetation in central and southeastern Arizona at about 4000–5500 feet (lower margin of the Upper Sonoran zone). Paleobotanical evidence thus supports the presence of late Tertiary uplands in central Arizona inferred from the regional geology. But the frequency of fossil pine pollen is low (relative to productivity of modern species) for an elevation where pine now largely dominates the vegetation of central Arizona. The inference is that the basin of deposition was lower and/or the climate drier (average annual rainfall at Prescott (5355 feet) *ca.* 18 inches) when the polliniferous sediments were deposited. The presence of *Betula*, *Alnus*, and *Ulmus* in the microflora appears to raise rather than lower the moisture requirements of the vegetation, but their scarcity suggests distant transport from more mesic uplands.

THRUST-FAULTING LIMITS IN WESTERN UTAH

Lehi F. Hintze
Brigham Young University, Provo, Utah

Magnitude of movement on thrust faults exposed in Basin and Range fault blocks has been difficult to estimate because extent of thrusts cannot be traced under Basin fill. Minimum displacement figures may usually be obtained by measuring the horizontal extent to which an allochthon now covers an autochthonous area, but maximum figures can seldom be determined by such direct measurement because of concealment problems. Recent mapping and stratigraphic work, however, have permitted delimitation of maximum movement on three thrust faults in Utah.

The Nebo thrust (possibly the southern continuation of the Charleston-Deer Creek thrust) has a minimum horizontal displacement of about 6 miles near Nephi, Utah. Total horizontal deformation may be twice this amount considering isoclinal folds in the allochthon. Maximum movement here may be measured by comparing the stratigraphy of the allochthon with known sections to the west in the direction from which the allochthon came. Consistent progressive facies changes in lower Paleozoic strata from the Nebo allochthon to Long Ridge and Tintic sections indicate that total displacement of the Nebo allochthon was probably no more than 12 miles.

The Pavant thrust near Kanosh, Utah, shows a minimum of 7 miles horizontal displacement, not including deformation represented by overturned folds. Maximum displacement, estimated by comparing allochthon stratigraphy with sections to the west, may be as much as 25 miles.

Horizontal deformation on the Needle thrust near Garrison, Utah, may be estimated structurally as the thrust fault passes northward into a fanfold. Shortening of 8 to 10 miles is postulated.

PRIMARY STRUCTURES IN PYROCLASTIC ROCKS OF THE OAK SPRING FORMATION (TERTIARY), NORTHEASTERN NEVADA TEST SITE, NYE COUNTY, NEVADA

Fred. N. Houser and F. G. Poole
U. S. Geological Survey, Federal Center, Denver, Colo.

The Oak Spring formation in the Nevada Test Site consists mainly of massive to bedded pyroclastic rocks as much as 2300 feet thick deposited on an irregular surface with a local relief as great as 1500 feet.

Bedding attitudes in the basal part of the pyroclastic sequence are directly related to the irregularities of the buried surface and locally show dips as steep as 40°, although angles near 30° are more common. Units farther from the buried surface have successively lower dips because the irregularities

tend to be subdued by continued deposition, erosion, and redistribution of volcanic material. The pyroclastic units lap onto or drape over buried ridges and fill valleys forming primary anticlines and synclines.

Many other sedimentary structures including contorted strata, cross-strata, ripple marks, and erosional unconformities characterize parts of the Oak Spring formation.

In many areas tectonic tilting, folding, and normal faulting have modified the primary folds in the pyroclastic rocks. Because of the similarity of the primary folds, formed during deposition of the Oak Spring formation, to folds formed by tectonic activity, care is required to distinguish the two types.

STRUCTURAL GEOLOGY AND STRUCTURAL CONTROL OF MINERAL DEPOSITS IN AN AREA NEAR NOME, ALASKA

C. L. Hummel
U. S. Geological Survey, Menlo Park, Calif.

Two structure systems have been delineated in the regionally metamorphosed bedrock of an area near Nome, Alaska. The older system, formed penecontemporaneously with the metamorphism, once consisted of a series of broad, open folds 10–30 miles wide and as much as 100 miles long, which extended northward across central Seward Peninsula. Later deformation gave rise to the younger system of structures, leaving only deformed relict parts of the older folds.

The younger structures reflect strong vertical movement. The principal structure is an eastward-trending uplift which formed the present Kigluaik Mountains. The north and south margins of the uplift and the mountains are marked by steeply dipping normal faults, and the center of the uplift is marked by the axis of an arch along which lie the highest points in the range.

Other structures belonging to the younger system include folds of considerable size, which formed on the crumpled limbs of the older folds, and a group of northeast-trending transcurrent faults. Gold-bearing lodes of the Nome goldfields are closely associated with both types of younger structures; the richest gold beach placers of the area were derived from a mineralized transcurrent fault which intersects the coast near Nome.

GARLOCK AND DEATH VALLEY FAULT ZONES IN THE AVAWATZ MOUNTAINS, CALIFORNIA

Richard H. Jahns and Lauren A. Wright
California Institute of Technology, Pasadena, Calif.; California Division of Mines, Los Angeles, Calif.

The rugged Avawatz Mountains, south-southeast of Death Valley, are crescentic in plan and have a prominent front that bulges broadly northeastward. The main mass of the range is a structurally high, lenslike block composed chiefly of earlier Precambrian plutonic and metamorphic rocks. This block, 14 miles long and 1–5 miles wide, is bounded and broken by faults of large displacement. Southwest of it a slightly larger and structurally much lower block contains thick sections of layered Mesozoic and Tertiary rocks.

The east-trending Garlock fault zone and the southeast-trending Death Valley fault zone, each 1–3 miles wide, join in the northwestern part of the range, where individual breaks truncate one another in a highly complex pattern. Within the area of junction are numerous fault-bounded slices of later Precambrian, Paleozoic, Mesozoic (?), and Cenozoic rocks; these are especially common along the flanks of the range. In a broad way, each fault zone partly merges with and is partly deflected by the other. Evidence of strike-slip movement and much stronger evidence indicating vertical displacements of tens of thousands of feet are present along both fault zones.

Nearly all the faults dip steeply, and none can be interpreted as a major thrust. The plexus of breaks is resolved beyond the area of junction into two major fault zones about 4 miles apart. These

trend southeastward toward Old Dad Mountain and the Providence Mountains. Associated breaks trend south-southeastward toward the Soda Mountains, but these appear to be second-order features.

PALEOZOIC SECTION IN THE ARROW CANYON RANGE, CLARK COUNTY, NEVADA

R. L. Langenheim, Jr., B. W. Carss, J. B. Kennerly, V. A. McCutcheon, and R. W. Waines
University of Illinois, Urbana, Ill. (Langenheim, Carss, Kennerly); University of California, Berkeley, Calif. (McCutcheon, Waines)

Ordovician through Permian rocks are approximately 10,000 feet thick. Cambrian black dolomite and fossiliferous, argillaceous limestone are unmeasured. Ordovician rocks include 2434 feet of Pogonip Group comprising seven limestone or dolomite formations, 140 feet of Eureka quartzite with a fossiliferous upper member, and 337 to 388 feet of Ely Springs dolomite. The Silurian Laketown dolomite thins southward from 403 to 257 feet because of pre-Devonian erosion. Three new Devonian formations and the Crystal Pass limestone aggregate 1970 feet. The lowermost 320-foot, buff, cliffy dolomite formation contains *Acrospirifer kobhana* at the base and is capped by a *Stringocephalus* biostrome. Above this a 300-foot, bench-forming, buff dolomite and limestone formation is succeeded by 1070 feet of black limestone cliffs with interbedded dolomite and quartzite. The Crystal Pass limestone is 229 to 280 feet thick. The Monte Cristo limestone, 1415 to 1467 feet thick, includes all Hewett's members except the Arrowhead limestone. The 3434-foot Bird Spring formation comprises five units. The basal, 79-foot, dark-gray, medium-grained limestone unit includes a calcareous basal sandstone. *Stigmaria* sp. occurs associated with marine fossils just below the base of the prominent succeeding black shale and argillaceous limestone unit. *Rhipidomella nevadensis* occurs at the base of the succeeding cyclic limestone unit. Above this, a unit of interbedded limestone and argillaceous, cherty limestone is succeeded by a white, cliffy dolomite and limestone unit. The top of the Bird Spring formation is not exposed.

PATTERNS OF STRUCTURAL GEOLOGY IN THE NORTHERN PART OF SOUTHEASTERN ALASKA

Ernest H. Lathram

Large blocks separated by major lineaments in northern southeastern Alaska exhibit different structural patterns. In the Coast Range belt, on the mainland, closely spaced folds trend northwest, are isoclinal, and overturned to the southwest. Plutonic rocks are usually well foliated, parallel to the foliation of older rocks; migmatite is common. Major structures of the Admiralty Island block are broad northwest-trending composite folds, most overturned to the southwest but some to the northeast. Large plutons are moderately foliated, migmatite is common. In the Chilkat Range block, south of L. 59° N., closely spaced folds trend northwest, are isoclinal and overturned to the southwest in the east, tight and asymmetrical with steep southwest limbs in the west. Plutons are small, unfoliated, have sharp contacts and narrow contact metamorphic zones. From 59° N. to Takhin River folds apparently trend northeast; plutons are large and well foliated. In the northeast Chichagof block (northeast of Mud Bay–Sitkoh Bay lineament) folds are broad, symmetrical, trend west-northwest. Plutons are small; most of them are unfoliated, have sharp contacts, and show few contact metamorphic effects. In the western Chichagof belt the folding is not well known. Beds dip predominantly southwest. Plutonic rocks are commonly well foliated, parallel to foliation of older rocks; migmatite is common.

Most faults are steep. Northwest-trending faults predominate, most are right lateral or reverse, northeast side upthrown except in the west Chichagof belt. Most east-trending faults are normal, north side downthrown. Some northeast-trending faults are apparently left lateral. East-, northeast- and north-trending faults are rarely well expressed in metamorphosed areas.

PORPHYRY INTRUSIVE ROCKS OF THE MANHATTAN DISTRICT, NORTHERN FRONT RANGE, COLORADO

William N. Laval and Allan E. Miller
Department of Geology, Colorado State University, Fort Collins, Colo.

A belt of intrusive rocks regarded as of probable Laramide age by Lovering and Goddard (1950) trends northeast in the Front Range west of Fort Collins, Colorado. It parallels the central Colorado intrusive belt to the south and contains granodioritic and monzonitic porphyries similar to those in the larger and better-known belt.

In the Manhattan mining district the country rocks are Precambrian quartz-biotite schist, hornblende schist, and granitic rocks. Detailed mapping shows the porphyry to be dikes, sills, and small stocks. Tabular bodies are most abundant and are from a few feet to 200 feet wide and up to 1½ miles long. Most of them are discordant to the country rock foliation but locally parallel it. The stocks are irregularly shaped and formed at the intersections of dikes. Most of the dikes follow east-west and northwest-southeast joints and shear zones that parallel major Laramide structural trends. Arcuate outcrop patterns suggestive of ring dikes result where dikes followed gently curving schist–granite contacts.

Although mineralized shear zones are common near the intrusive rocks, there is little evidence of wall-rock alteration indicative of potentially commercial deposits.

DISTRIBUTION OF THE CHEMICAL ELEMENTS IN THE SALINES OF SALINE VALLEY, INYO COUNTY, CALIFORNIA

Oreste W. Lombardi
Oceanic Research Division, Research Department, Michelson Laboratory, U. S. Naval Ordnance Test Station, China Lake, Calif.

Saline Valley is a deep depression in the Basin and Range province containing $NaCl$-Na_2SO_4 deposits of Pleistocene and recent origins.

The distribution of major and minor constituents in the salts, brines, muds, ground waters, and springs of Saline Valley were investigated. Several centers of evaporation were found on the playa, and their assemblages of major and minor constituents differ.

Anomalous concentrations of Li, K, Rb, Mo, W, I^-, IO_3^-, $CO_3^=$, $SO_4^=$, and borates were found in the salines, some of which were traceable to source areas. Li, K, Rb, and to a certain extent B were found to be controlled largely by clay minerals. Li, K, Rb, and Cu are taken up by clays along the playa margin, and the alkaline earths are quantitatively precipitated as carbonates along the playa margin leaving Cl^-, $SO_4^=$, $CO_3^=$, Br^-, IO_3^- and borates to concentrate in the centers of evaporation.

Anomalous concentrations of Li, K, Rb, Mo, W, I^-, IO_3^-, $SO_4^=$, $CO_3^=$, and borates were found in the salines, some of which were traceable to source areas. Many of the trace elements in the brines were found to be related to or controlled by the ratio of alkaline earths to carbonate or bicarbonate in the incoming ground water.

O^{18}/O^{16} RATIOS AND SR AND MG CONTENTS IN RECENT AND FOSSIL ARTICULATE BRACHIOPODS AND THEIR RELATIONSHIP TO THE WATER CHEMISTRY

Heinz A. Lowenstam
California Institute of Technology, Pasadena, Calif.

For recent brachiopod shells it is shown that the Sr and Mg concentrations, like the O^{18}/O^{16} ratios, depend upon temperature and the water chemistry. In shells from waters chemically similar to the

average of the oceans, the relationship of the O^{18}/O^{16} ratios to the Sr and Mg concentrations is essentially dependent only on temperature, as the water corrections for the O^{18}/O^{16} ratios and Sr and Mg concentrations are small. Samples from hypersaline waters, enriched in O^{18}, Sr, and Mg concentrations relative to mean ocean waters, have O^{18}/O^{16} ratios which are more positive and have higher Sr and Mg concentrations than samples from the same temperatures in mean ocean waters. A sample from hyposaline water, depleted in O^{18}, Sr, and Mg concentrations relative to mean ocean water, has a more negative O^{18}/O^{16} ratio and lower Sr and Mg concentrations than samples from the same temperature in mean ocean water. Therefore the relationships of the O^{18}/O^{16} ratios to the Sr and Mg concentrations in the shells can be used to distinguish samples from waters of different water chemistry.

In several fossil brachiopods (Pliocene to Mississippian) the relationship of the Sr concentrations to the O^{18}/O^{16} ratios is similar to that of recent samples from mean ocean waters, while in two other samples (Permian) it is similar to recent shells from hypersaline waters. The relationships of the Mg concentrations to the O^{18}/O^{16} ratios in two fossils are close to recent samples from mean ocean waters; in the other fossils they are diagenetically modified.

GEOLOGY OF THE PRIEST RAPIDS AND WANAPUM DAM SITES ON THE COLUMBIA RIVER IN SOUTH-CENTRAL WASHINGTON

J. Hoover Mackin
Department of Geology, University of Washington, Seattle, Wash.

The master plan for development of the Columbia River called for a 175-foot dam at Priest Rapids. Permeability of a high gravel terrace constituting the left abutment was a controlling factor in the decision to split the head between two dams, Priest Rapids, now substantially completed, and Wanapum, now being built.

Priest Rapids dam is about 8000 feet long. The spillway and powerhouse, 2000 feet long, are founded chiefly on a strong basalt flow which formed the rapids. One interflow contact accepted 30 cubic feet of grout per linear foot of curtain; except for this contact, the basalt is essentially impermeable. Low terraces of gravel on both sides of the valley are spanned by earth-embankment segments; rolled-fill cutoffs extend to rock. An upstream blanket 1000 feet long seals the face of the high terrace on the left side of the valley.

At the Wanapum site the rock surface is covered by 50–300 feet of alluvium across the entire 8000-foot width of the valley floor. The spillway and powerhouse are on a buried ridge formed by differential erosion in the axial part of a basalt anticline. Positive cutoff walls are required under the earth-embankment segments of the dam, but, because the rock surface is far below river level, placement of a conventional rolled fill, in the dry, is impracticable. Cutoff walls are being constructed by digging narrow, vertically walled trenches, kept full of bentonite slurry to prevent caving, and backfilling with well-graded sand and gravel blended with the bentonite slurry.

FOUNDATION FAILURE AT MALPASSET DAM NEAR FREJUS, FRANCE

E. C. Marliave
4466 North Park Drive, Sacramento, Calif.

On December 2, 1959, a 200-foot high thin-arch dam across the Reyran River in France collapsed. The resulting flood caused damage in the millions and took 424 lives. The dam, only 5 years old, had just filled for the first time during unprecedented rains.

The structure was founded on a sheared jointed mass of mica schist, and failure occurred under the central left abutment, where intersecting joint planes roughly parallel to the arch created a V-shaped mass of crushed rock overlying a clay seam. The left side of the arch was largely founded on the crushed wedge.

Apparently, movement resulting from saturation, weakening, and movement of this wedge transferred greater thrust to other portions of the arch. This action resulted in the movement of the small, left-end thrust block, in less competent material, about 2 feet downstream and upward a similar amount. The lower right side of the arch at channel elevation moved downstream about 2 feet, crushing the foundation rock. The left three-fourths of the dam then collapsed.

GEOLOGY OF THE ESCALANTE-BOULDER AREA, SOUTH-CENTRAL UTAH

C. Carew McFall

The Escalante-Boulder area is in the Colorado Plateau province in south-central Utah; it comprises 583 square miles on the southern slopes of the 11,000-foot, lava-capped Aquarius Plateau.

Jurassic, Upper Cretaceous, and Tertiary strata totaling 12,000 feet are exposed in the area. The pre-Tertiary beds have been involved in monoclinal folding and are overlain in angular unconformity by nearly horizontal Tertiary strata. A few relatively small, normal faults cut both the Tertiary and older rocks.

In the Jurassic San Rafael group, correlation is made between the Carmel formation of the San Rafael Swell region and the beds presently called Carmel formation, Entrada sandstone, and Curtis formation in the Bryce Canyon and Zion Canyon areas and also between the Entrada sandstone of the San Rafael Swell region and the Windsor formation of southwestern Utah.

The lowest Tertiary beds, which are orange pink, are evidently correlative with the Flagstaff limestone of late Paleocene and early Eocene age rather than with the Wasatch formation.

The regional orogenic history which has been worked out in central Utah by E. M. Spieker is substantiated by the sedimentary record in the Escalante-Boulder area. Some added evidence for Spieker's pre-Flagstaff movement is the 170-foot thick cobble conglomerate at the base of the orange-pink beds. This conglomerate is apparently a by-product of folding and overthrusting to the northwest which was very likely contemporaneous with the monoclinal folding of the Colorado Plateau.

UPPER CRETACEOUS FORAMINIFERA FROM VANCOUVER ISLAND, BRITISH COLUMBIA, CANADA

Alan McGugan
Micropaleontological Consultant, Calgary, Alberta

Previous geological work is summarized by Usher (1951). The Cretaceous lies in two basins, the Comox basin in the north, and the Nanaimo basin in the south, separated by a pre-Cretaceous ridge.

The succession consists of alternating marine shales and nonmarine sandstones. From bottom to top, the shales of the Nanaimo basin are named the Haslam, Cedar District, and Northumberland formations. Those of the Comox basin are the Qualicum, Trent River, Lambert, and Spray formations.

The Foraminifera represent restricted and open marine biofacies; the former is not considered here. The lower parts of the Haslam, Qualicum, and Trent River formations are typified by large lagenids together with *Gaudryina* cf. *limbata* and occasional *Globigerina*. This fauna is probably Campanian in age. The Cedar District, Northumberland, Upper Trent River, and low Upper Lambert formations contain *Anomalina henbesti* and 18 other genera. This fauna is Late Campanian in age; it corresponds to faunas of Taylor and early Navarro age in California. The uppermost part of the Lambert formation contains *Bolivina incrassata*, *Bulimina* cf. *petroleana*, spinose *Globorotalites*, *Allomorphina*, and *Globigerinella*. This fauna is early Maestrichtian in age and corresponds to P. P. Goudkoff's D-1 and D-2 zones in the Navarro of California. The Spray formation is unfossiliferous. The Campanian-Maestrichtian boundary is thus placed within the Lambert formation, slightly higher than the level used by Usher.

ADVANCE OF THE MULDROW GLACIER 1957

Marion T. Millett
Brigham Young University, Provo, Utah

The Muldrow Glacier is located on the northeast slope of Mt. McKinley in the Alaska Range, Alaska. Since earliest observations the glacier has been stagnant with a smooth surface throughout its length. The terminus has a heavy debris cover with vegetation well established.

In January 1957 it was first noticed that the glacier appeared to be changing. In July an I.G.Y. party began studying what proved to be one of the most spectacular glacial advances ever documented. Beginning sometime in the winter of 1956–1957 and until August 1957, parts of the Muldrow and its tributaries advanced as much as 4 miles. The entire glacier has undergone a complete change. Although much of the Muldrow lies athwart a fault zone no significant seismic activity was recorded. Climatic data show no evidence of increased snowfall, and no other glacier in the vicinity shows any signs of activity.

The reservoir lag theory of Tarr and Von Engeln is proposed as a partial solution to the mysterious rapid advance. The surface of the upper part of the glacier has dropped as much as 200 feet from its position in 1954. The surface of the terminal area has thickened about 200 feet. Features around the terminus suggest that similar rapid advances occur periodically.

SEISMIC ACTIVITY IN BRITISH COLUMBIA

W. G. Milne and K. A. Lucas
Dominion Observatory, Victoria, British Columbia

The list of earthquakes from the mid-1880's to 1951 was compiled from seismological catalogues and from newspaper files. From 1951 to date, a network of sensitive seismographs has located the smaller tremors in the southwestern area. Since 1957, when these seismographs were calibrated with the Willmore bridge, magnitudes have been obtained for each earthquake. Maps showing the distribution of epicenters are shown.

DIFFERENTIAL THERMAL ANALYSIS OF SHATTUCKITE

Ming-Shan Sun
New Mexico Institute of Mining and Technology, Bureau of Mines and Mineral Resources Division, Socorro, N. M.

Dark-blue radiated shattuckite from Ajo, Arizona, is used in the differential thermal analysis. The thermal curve is traced on a Leed and Northrup micromax recorder: heating rate 12°C per minute; scale factor $\times$ 20, which corresponds to 10 microvolts per division of the graph paper; particle size of sample below 100 mesh.

The thermal curve is characterized by a prominent endothermal peak and a small exothermal peak. The endothermal peak has a peak temperature of 774°C, peak height 210 microvolts, and peak range 700°C to 800°C. The cooling effect actually starts at 430°C and increases rapidly at 700°C. The exothermal peak has a peak temperature of 980°C, peak height 60 microvolts, and peak range 970°C to 990°C.

The endothermal peak indicates dehydration and decomposition of shattuckite into cryptocrystalline tenorite, some amorphous silica, and copper silicate(?), which were identified by X-ray powder diffraction method. Sample heated to 950°C contains tenorite and cryptocrystalline alpha quartz, whereas copper silicate(?) disappears. Sample heated to 1,000°C contains tenorite, cuprite, and alpha quartz. Because cuprite has greater free energy of formation than does tenorite, some tenorite in the sample is decomposed into cuprite at about 800°C. The exothermal peak indicates the crystallization of alpha quartz.

The total loss of weight of 3.87 per cent begins at 900°C. According to the total loss of weight, the formula of shattuckite should be $3CuSiO_3 \cdot H_2O$, instead of $2CuSiO_3 \cdot H_2O$. A small percentage of the loss of weight is due to the decomposition of some tenorite into cuprite.

LARGE OVERTHRUSTS IN THE NORTHWESTERN CASCADES NEAR THE 49TH PARALLEL (WHATCOM AND SKAGIT COUNTIES, WASHINGTON, AND LOWER TOMYHOI CREEK AREA, BRITISH COLUMBIA)

Peter Misch

Department of Geology, University of Washington, Seattle, Wash.

Of two westward overthrusts west of the crystalline backbone of the Northern Cascades, the lower (Church Mountain thrust = I) brings Upper Paleozoic over Jurassic-Lower Cretaceous rocks, the upper (Shuksan thrust = II) low-grade Cascade metamorphic rocks of pre-Jurassic and otherwise uncertain age over the Upper Paleozoic. After latest Cretaceous-Paleocene deposition the thrusts were folded.

Thrust I forms the large Nooksack North Fork anticlinal window and re-emerges north of the border (Tomyhoi Creek), continuing across the Chilliwack.

Thrust II is preserved east and west of the window. Its steep root southward crosses the Skagit. Farther south J. A. Vance mapped the same thrust.

At thrust II and within the highest part of the underlying plate occur mylonitic slices of pre-Carboniferous and pre-Cascade-metamorphic "basement" crystalline rocks, identical with those of the klippen mapped by R. S. Yeats 50 miles south of the Skagit. Sheared ultrabasic rocks in the thrust zone suggest a root extending to great depth.

Internally, the thrust plates are complexly folded and imbricated. Subsidiary thrusts within the Upper Paleozoic plate and klippen of the basement crystalline rocks and of the overlying upper-plate metamorphic rocks are spectacularly exposed around Tomyhoi Peak. Equally spectacular are recumbent folds within the Upper Paleozoic plate north of the border and within the upper plate southwest of Glacier.

Throughout the area, major and minor folds and cleavage confirm westward movement (disregarding superposed Tertiary deformation). Yielding is southwestward on the south, westward near the border, northwestward north of it. The system here forms a westward convex arc, marking the northern termination of the much larger, eastward convex "arc of the Pacific Northwest."

WEST CORDILLERAN METAMORPHIC AND GRANITIC EVOLUTION

Peter Misch

Dept. Geology, University of Washington, Seattle, Wash.

The following processes are discussed in their temporal and genetic relationships: regional metamorphism of different types (such as "Dalradian type", "glaucophanic type"); dominantly synkinematic granitization (production of migmatitic gneisses); static granitization; mobilization; anatexis; igneous granitic intrusion. As an example, the case history of the Northern Cascades is outlined.

Relations between metamorphic-plutonic and structural evolution are discussed. The great length of time commonly involved, and the repetitious nature of orogenic climaxes and of periods of thermal and chemical activation are emphasized.

REGIONAL STRUCTURE OF ROCKY MOUNTAINS IN THE JASPER AREA, CANADA*

E. W. Mountjoy
Geological Survey of Canada, Ottawa, Ontario, Canada

From east to west across the Foothills, Front Ranges, and Main Ranges of the Rocky Mountains there is a progressive increase in stratigraphic level from the Tertiary and Cretaceous of the Plains to Cambrian and Proterozoic of the Main Ranges.

The Foothills embrace several folded and complexly interlocked thrust sheets of Mesozoic and Paleozoic strata, about 40 to 100 miles in length. Northwest toward the Smoky River, Front Range structures lose stratigraphic throw, and resistant Paleozoic strata disappear beneath Mesozoic strata, and thus physiographically Front Ranges merge with Foothills. The Main Ranges, bounded on the northeast by the Pyramid thrust whose length exceeds 200 miles, consist of broadly folded Cambrian and Proterozoic rocks. Two important thrusts occur in the Mount Robson district, and a culmination is present west of Jasper.

Thrust faults consistently follow particular stratigraphic zones within the Upper and Lower Cretaceous, Mississippian, Upper Devonian, and Middle Cambrian rocks of the Foothills and eastern Front Ranges, and within the Cambro-Ordovician strata of the western Front Ranges. The Pyramid thrust may follow horizons low in the Proterozoic sedimentary succession.

Toward the northeast, the gross tectonic (strain) pattern is one of increasing complexity and decreasing persistence of thrust faults across the Front Ranges into western Foothills and decreasing complexity across the eastern Foothills. From this tectonic pattern and the presence of steeply dipping, rotated thrust sheets in the Front Ranges and Foothills, it is suggested that initiation of thrusts occurred progressively from southwest to northeast.

OBSERVATIONS OF PHASE VELOCITY FOR RAYLEIGH WAVES IN THE PERIOD RANGE 100–400 SECONDS

John E. Nafe and James N. Brune
Lamont Geological Observatory, Palisades, New York

Phase velocity as a function of period has been determined for Rayleigh waves in the period range 100–400 seconds. The results were derived from a study of seismograms from the Southeastern Alaska earthquake of July 10, 1958, and from published data on the Assam earthquake of August 15, 1950. The method depends on measurement of the travel time of wave crests along an arc of known length with proper correction for change of period with distance. For observations of a single Rayleigh-wave train at a single pair of observing stations crest identification is uncertain and so too is the resulting phase-velocity period curve. A set of phase-velocity curves may be computed, each corresponding to a different choice of crest identification. Only one of these is consistent with the data from several earthquakes and several pairs of observing stations. In the present work, high precision in phase-velocity measurement is achieved by using the observations of the Rayleigh waves R_3 and R_5 at Pasadena of the Assam earthquake. Data from the Southeastern Alaska earthquake are used to resolve the ambiguity resulting from uncertainty in crest identification. The final phase-velocity curve is estimated to be accurate to within 1 per cent in the range of periods 100 to 400 seconds.

STRATIGRAPHIC RANGE OF *OGYGOPSIS*

C. A. Nelson
University of California, Los Angeles, Calif.

The trilobite genus *Ogygopsis* is reported in the literature as confined to beds of Middle Cambrian age. Earliest reports of the type species, *Ogygopsis klotzi*, from the Canadian Rockies suggested a re-

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striction to beds high in the Middle Cambrian succession. Later work by Rasetti in the same area demonstrated a range throughout nearly all the Middle Cambrian strata. The genus and its synonym or close relative *Taxioura* have also been reported from Middle Cambrian strata in the Wasatch region of Idaho and Utah, from northeastern Washington, and from the Inyo Range, California.

Recent study of the Inyo region has demonstrated that *Ogygopsis*-bearing beds, reported by Kirk as Middle Cambrian, clearly underlie strata containing *Olenellus* and other elements of the late Early Cambrian fauna. Detailed mapping throughout the Inyo region has ruled out the possibility of overthrusting as an explanation of the seemingly anomalous occurrence.

Further confirmation of the extension of the age of *Ogygopsis* is found at Miller Mountain, Nevada. The Miller Mountain formation, reported as Lower Cambrian on the basis of olenellid materials, has yielded a variety of faunas including abundant *Ogygopsis* from its upper beds. Of special significance is the occurrence of *Olenellus* and *Ogygopsis* on the same bedding surface. Clearly the genus *Ogygopsis* has a stratigraphic range from upper Lower Cambrian through Middle Cambrian.

SOME OBSERVATIONS OF LONG-PERIOD SEISMIC WAVES

Jack Oliver
Lamont Geological Observatory, Palisades, N. Y.

Comparison of seismic waves recorded by similar long-period seismographs at a variety of geographical locations provides additional information on several kinds of seismic-wave propagation. The *PL* wave—*i.e.*, the long-period wave train following the initial P-wave at small to moderate epicentral distances—is widely recorded throughout the world. This wave appears to be controlled by the near-surface wave guide and is potentially of value for studies of crustal and mantle structure. The dispersive properties of most of the surface waves recorded at all stations may be explained quantitatively through the use of normal mode theory for structures approximating the continental or oceanic crust-mantle systems, or a combination of the two. Certain differences in the recorded waves do exist, however, which depend upon the path and, in some cases, apparently upon the site of the recording station.

BRANNERITE WITH GOLD FROM PLUMAS COUNTY, CALIFORNIA

A. Pabst and Melvin C. Stinson
University of California, Berkeley, Calif.; California Division of Mines, San Francisco, Calif.

Brannerite is associated with gold at the Little Nell "mine", located at an elevation of 3300 feet in the SE ¼ sec. 35, R. 8 E., T. 23 N., Bucks Lake quadrangle, Plumas County, California, on the north slope of the canyon of the Middle Fork of the Feather River. Long ago gold was mined here and at several nearby localities. Radioactivity was detected by Mr. Perry L. Jones, one of the holders of claims in the area, in old stopes, now caved and partly reopened, on both sides of a nearly vertical 5-foot albitite dike striking N. 45° W. Brannerite was identified early in 1957 in specimens brought in by Mr. Jones, who later kindly guided the writers on visits to the locality.

The rock on both sides of the dike is a soft, lustrous, black schist, mapped by H. W. Turner (1898) as Calaveras formation. The schist is mostly fine-grained dolomite, talc, and graphite with minor chlorite and quartz and scattered specks of pyrite. The stopes are in this rock which was mined to the walls of the dike. The dike rock consists of abundant, partly sericitized, albite phenocrysts, up to .5 cm, and scarce, slightly larger, quartz phenocrysts in a sericitized groundmass with scattered minute pyrite cubes. Narrow, vuggy veins of clear albite with some isolated quartz crystals cut the dike transversely. Some veinlets of dolomite are also present. Brannerite, mostly in broken crystals, up to 1 cm long, is confined to a narrow zone along the dike wall and adjoining fractures. Some is in the albite vugs. Gold, where in contact with brannerite, coats the broken crystals and is clearly later.

The brannerite is metamict and of density *ca.* 4.9. Heated fragments yield an X-ray powder diffraction pattern identical with that of type brannerite. Much of the brannerite has a yellow alteration coating of cryptocrystalline anatase.

ENIGMATIC CRETACEOUS PELECYPOD GENUS *MEEKIA*

W. P. Popenoe and L. R. Saul
Dept. Geology, University of California, Los Angeles, Calif.

The genus *Meekia* was proposed by Gabb in 1864 to include three new California Upper Cretaceous pelecypod species: *M. sella*, *M. radiata*, and *M. navis*. The genus is known only in deposits bordering the North Pacific Ocean, and by far the largest number of specimens is reported from the west coast of North America. The temporal range of the genus extends from Albian through Maestrichtian, and at least a dozen species having restricted temporal ranges can be recognized. Of Gabb's original species the stratigraphic position is known only for the type species *M. sella*; it is restricted to the Maestrichtian. *Meekia cuspidata* (Whiteaves), based on internal impressions, from Maud Island, B. C., may be of Albian age. The age of *M. radiata* is unknown; *M. navis* probably is not a *Meekia*. All other species are as yet unnamed.

The genus has been placed in the families Tancrediidae, Trigoniidae, and Verticordiidae, but belongs in none of them. The systematic position is still in doubt. Internally the shells show a much modified lucinoid dentition and an entire pallial line. Shells of Santonian and younger age gape at both ends.

All species seem to have inhabited a similar and somewhat restricted environment. *Meekia* in association with a characteristic assemblage of other genera is found commonly in coarse to medium-grained sandstone, suggesting a shallow-water habitat.

GEOLOGY OF THE FRASER VALLEY FROM HOPE TO EMORY CREEK, BRITISH COLUMBIA

Peter B. Read

The Fraser Valley from Hope to Emory Creek is underlain by mainly regionally metamorphosed Paleozoic and (?) Mesozoic sedimentary and volcanic rocks.

The Chilliwack group consists of iron- and magnesium-rich pelitic schists and minor basic schists of the staurolite-quartz subfacies and the sillimanite-almandine subfacies.

The Hozameen group, which generally consists of cherts, phyllites, and greenstones of the greenschist facies, is raised to the almandine amphibolite facies at its western boundary. The Custer granite gneiss is an ancient complex of sedimentary and volcanic rocks. During the regional metamorphism of the Custer, it formed gneisses and pegmatites, became mobile, and, limited by the structure of the surrounding rocks, moved into an area of less intense metamorphism. The movement caused a shearing of the Custer to form augen gneisses and of the adjacent rocks to form phyllonites. Later release of stresses caused closely spaced faulting of the Custer and the wall rocks. A band of sheared quartz diorite and gneiss separates the Hozameen group from the Custer. The quartz diorite intrudes both units. Unmetamorphosed conglomerates of the Jackass Mountain group unconformably overlie the Custer.

A northerly trending dip-slip fault formed above the Lower Miocene has downfaulted the rocks east of the Chilliwack group. The fault extends from Spuzzum to Chilliwack River and possibly into northern Washington. Its trace south of Hope has been partly obliterated by the intrusion of the younger Chilliwack batholith. An early period of folding (Jurassic?) is associated with the movement of the Custer, and a later period (post-Early Cretaceous) with the formation of a northerly trending anticline that occupies the center of the Fraser Valley.

TOURMALINIZED FRANCISCAN SEDIMENTS AT MT. TAMALPAIS, MARIN COUNTY, CALIFORNIA

Salem J. Rice
California Division of Mines, Ferry Building, San Francisco, Calif.

An interesting type of rock alteration involving boron metasomatism occurs at the East Peak of Mt. Tamalpais, where sediments of the Franciscan formation are tourmalinized. These altered rocks, which crop out in an irregularly shaped area roughly a quarter by half a mile in maximum dimension, were largely graywacke and shale, but now consist chiefly of quartz and brown tourmaline. Alteration took place principally by replacement of feldspar and matrix material by fine-grained tourmaline. The clastic quartz grains apparently were not affected, except possibly in some of the highly altered, fine-grained rocks where relict textures are not recognizable. Tourmaline commonly constitutes 25 per cent or more of the rock and in places accounts for more than 50 per cent. One specimen of tourmalinized graywacke, clearly identified by its relict textures, yielded 5.50 per cent B_2O_3. The analysis further shows the probable removal of much of the CaO, K_2O, and Na_2O in the rock. Otherwise the analysis is essentially similar to those available of Franciscan graywacke from other localities.

Tourmaline also occurs in vugs as white (rarely green) needles and stubby brown prisms. A relatively shallow origin is suggested by the abundance of these vugs in the altered rock.

EVIDENCE FOR POSSIBLE EUSTATIC FLUCTUATION IN PERMIAN SEA LEVEL

J. Keith Rigby
Pan American Petroleum Corporation, Calgary, Alberta

Synchronous transgressive and regressive reef-limestone development is apparent in such widely scattered areas in West Texas and New Mexico as the Guadalupe Mountains, Chinati Mountains, and Glass Mountains. Transgressive and regressive stratigraphic relations have also been observed in marine and nonmarine units exposed in the Grand Canyon, Arizona, in eastern Nevada, in northern and central Utah, and in western Wyoming. Limited observations in Pacific Coast regions suggest similar stratigraphic conditions. Review of literature from the Pacific and Arctic coasts of North America, and of eastern and western Asia and Europe, suggest similar transgressive and regressive relations.

Major transgression took place in Leonardian time, reaching maximum extent near the end of the epoch or immediately following the end of the epoch; in Late Wordian time; and in Medial Ochoan time. Major regressions took place in Wolfcampian, Early Guadalupian, Late Guadalupian, and Late Ochoan time.

Essentially synchronous transgression and regression, in widely scattered areas of obviously different structural behavior, strongly suggest eustatic fluctuations of sea level rather than a mutual epeirogenic control.

OPTICAL AND TWIN ORIENTATION OF SPURRITE

Abraham Rosenzweig
University of New Mexico, Albuquerque, N. M.

Contact-metamorphosed limestone on the east flank of the Tres Hermanas Mountains, Luna County, New Mexico, contains considerable amounts of anhedral, twinned spurrite crystals. Although the crystals have no planar boundaries, plane-bounded zonal growths are common. Two twin laws which produce 30-degree wedge-shaped segments have been noted. Previous descriptions of spurrite from Scawt Hill, Ireland, Velardeña, Mexico, and Crestmore, California, all refer to two twin planes at approximately 60°, but much confusion and inconsistency are apparent in these descriptions.

Suitably oriented twins of spurrite several millimeters in diameter were removed from thin sections after determining their optical orientation, and X-ray diffraction patterns of the several twin segments were obtained by the precession method. This technique permits the determination of cleavage, optical, and lattice orientation on the same sample. The diffraction patterns display pseudo-orthorhombic and pseudo-hexagonal symmetry. A prominent cleavage appears parallel to (001), and a poor one parallel to (100). The zonal-growth boundaries correspond to the planes (001), (100), (201), ($20\bar{1}$), and ($20\bar{7}$). The optical orientation is: X = b, $Z \wedge$ c = 59° to 67°. Simple and polysynthetic twinning occur with the composition planes ($20\bar{5}$) and (001), respectively. In a few instances simple twinning occurs alternately on each law, producing sixlings which appear, in thin section, as twelve 30-degree segments.

LOVE-WAVE DISPERSION IN A HETEROGENEOUS SPHERICAL EARTH

Y. Satô, M. Landisman, and M. Ewing
Lamont Geological Observatory, Palisades, N. Y.

The equation of motion for Love waves in a heterogeneous spherical earth, with suitable boundary conditions, has been solved numerically, using the modified Adams method. This method of solution of the dispersion problem is similar to that previously described by Satô for surface-wave dispersion in a heterogeneous flat earth.

The fundamental and several higher radial modes of vibration have been calculated for the Jeffreys-Bullen model and also for one proposed by Miss I. Lehmann as a result of shear body-wave studies.

PLIOCENE SILICIC IGNIMBRITES AND BASALT FLOWS IN THE BELLEVUE QUADRANGLE, IDAHO

Dwight L. Schmidt
University of Washington, Seattle, Wash.

A three-fold rhyolitic(?) ignimbrite sequence lies unconformably on Challis volcanic rocks, on sedimentary rocks of Carboniferous age, and on rocks of the Idaho batholith along the north-central margin of the Snake River Plains. Tuff A, the lowest, consists of clinopyroxene-bearing, crystal-poor, thin flow units with black glassy bases and highly welded upper parts. The lower ignimbrites have secondary-flow lineation conforming to the underlying topography. Tuff B is largely a single(?) thick, highly welded, yet porous, crystal tuff containing about 50 per cent coarse crystals. Tuff C consists of crystal-poor, lapilli-rich, thin flow units with black glassy bases and pumiceous upper parts.

The material of tuff A is believed to represent an early phase of crystallization of a deep, hot magma; that of tuff B, a shallower, cooler magma in an advanced stage of crystallization; and that of tuff C, a relatively volatile magma.

A quartz basalt, extruded soon after tuff B, is uniformly contaminated with about 20 per cent rhyolitic material; crystals of K feldspar, plagioclase, and quartz are resorbed and altered but are otherwise identical with the phenocrysts of tuff B and may represent mixing of basaltic and rhyolitic magma. This basalt contains highly altered gneissic xenoliths which may be equivalent to the rock that was melted to form the magma represented by tuff B.

Basalt of latest Pliocene to earliest Pleistocene age, similar to the Snake River olivine basalts, shows no contamination. Tuff B, the quartz basalt, and some of the olivine basalt extruded from the same north-northwest trending structural zone. This suggests that the rhyolitic magma was solidified by the time the olivine basalt erupted.

UNDERWATER DELTA OF FRASER RIVER, BRITISH COLUMBIA

Francis P. Shepard and W. H. Mathews
Scripps Institution of Oceanography, La Jolla, Calif.: Institute of Oceanography, University of British Columbia, Vancouver, B. C.

The Fraser Delta is being built west into the Strait of Georgia near Vancouver. Rate of advance is now shown to average across a 2½-mile front surveyed in detail 28 feet per year at the 300-foot depth and 14 feet per year at the 120-foot depth. Advance at depths shoaler than 100 feet is still slower, and here the front has locally and temporarily retreated. Interception, by dredging, of bedload sand in the lower, navigable, 20 miles of the river may be responsible for the slower growth of this upper part of the delta.

The foreset slope shows underwater gullies off the present mouth and off a mouth abandoned in 1859. These gullies stop part way down the slope, and farther on there is a series of mounds suggestive of landslide hummocks. Neither bottom topography nor bottom samples suggest that turbidity currents play an important part in the evolution of this delta front.

Most core samples are unstratified for their entire length. The sediments are predominantly silt and clay on the slope north of the main river mouth, but at and south of the mouth sand constitutes about 50 per cent. Fallout of sediment from the river water which spreads out over the Strait waters, especially north of the mouth, may contribute significantly to the sediment of the slope. Sediments display consistent increase in water content (and porosity) with depth and with distance north of the river mouth.

SEISMIC-REFRACTION STUDIES AT SEA NEAR SOUTHERN AND WESTERN ALASKA

George G. Shor, Jr.
University of California Marine Physical Laboratory of the Scripps Institution of Oceanography, San Diego, Calif.

Seismic-refraction stations were shot in deep and shallow water near the Alaska coast in 1956 and 1957.

The deep part of the Bering Sea has oceanic structure, with crustal thickness little greater than in the north Pacific. There is a large accumulation of sediment above the crust. Profiles at the foot and top of the continental slope near Unimak give crustal thicknesses intermediate between normal continental and oceanic values. The Bering shelf is composed of material with sedimentary velocities.

The Aleutian Ridge consists of material with velocities typical of volcanic islands, resting on a crust with normal oceanic velocity and depth below sea level.

A series of profiles were made up the Alaskan abyssal plain from areas with water depth of 4 km to the base of the continental slope where water depth is only 3 km. Sediment accumulations under the abyssal plain are not great, and thicken only moderately toward land. The Mohorovicic discontinuity does not change significantly in depth along this section, despite changes in water depth.

Normal oceanic crustal velocity (between 6½ and 7 km/s) was found on all these lines, as well as n shallow water through Dixon entrance and as far inland as Duke Island, near Ketchikan.

GEOLOGY OF THE BLACKHAWK LANDSLIDE, LUCERNE VALLEY, CALIFORNIA

Ronald L. Shreve
Department of Geology and Institute of Geophysics, University of California, Los Angeles, Calif.

Blackhawk Mountain in southern California stands at the eastern end of the rugged 4000-foot escarpment that separates the San Bernardino Mountains on the south from the Mojave Desert on the north. At the base of the mountain on the broad bajada slope of southeastern Lucerne Valley is

the Blackhawk landslide, a lobe of nearly monolithologic marble breccia 30 to 100 feet thick, 2 miles wide, and nearly 5 miles long. Geological and mechanical evidence shows that the Blackhawk landslide crossed the gently inclined alluvial slope not as a debris flow, but as a nearly nondeforming sheet of breccia moving more than 50 miles per hour.

This breccia is the youngest in a series of late Tertiary and Quaternary nonmarine sandstone, fanglomerates, and landslide breccias derived mainly from the gneiss, quartzite, Carboniferous marble, and Cretaceous quartz monzonite of the San Bernardino Mountains. All these rocks except quartzite are exposed on Blackhawk Mountain.

After deposition of the older sandstone, fanglomerates, and landslide breccias, weathered gneiss and resistant marble were successively thrust northward and upward over the uncemented sandstone. Then these rocks were deformed and further uplifted to their present positions by monoclinal folding along a northwest-trending line at the foot of the present mountain front. Finally, erosion of the gneiss and sandstone undermined the marble at the summit of Blackhawk Mountain and brought about the intermittent landsliding that culminated in the Blackhawk landslide.

GEOLOGY OF THE TEXADA IRON MINES, TEXADA ISLAND, BRITISH COLUMBIA

A. C. Skerl

This account describes the results of the geological mapping of the various pits as they have been extended and deepened during the past 4 years and of the underground exploration during the past year.

In the mine area up to 1000 feet of limestone rests on an older volcanic series, both of Late Triassic age. They were folded and then intruded by a quartz diorite stock and related dikes accompanied by the formation of skarn (mainly garnet-epidote) and magnetite with minor pyrite, chalcopyrite, and pyrrhotite.

The quartz diorite broke through the volcanic rocks and then "mushroomed" in the limestone to form overhanging structural traps that seem to have been so important in localizing the ore bodies.

The deposits of economic importance have replaced limestone or previously formed skarn.

Many of the numerous faults appear to have been active before, during, and after mineralization.

The following factors influenced the location of the ore and have proved to be valuable guides for exploration: (1) limestone with an overhanging contact of diorite, (2) proximity of the volcanic basement, (3) numerous faults with easterly strikes and various southerly dips, and (4) north-striking fold axes.

RELATIVE SPEED AND ACCURACY OF SOME METHODS OF MEASURING THE POSITION OF OPTICAL DIRECTIONS BY UNIVERSAL STAGE

David B. Slemmons and Terry E. Davis
Mackay School of Mines, University of Nevada, Reno, Nev.

Nearly all universal-stage work, whether in petrofabric studies or in descriptive mineralogy, depends on locating such optical directions as E and O, or X, Y, and Z. These optical directions are found by manipulating the axes of rotation of the universal stage so that each optical direction is aligned to the east-west axis of the universal stage; with crossed nicols the crystal will then remain dark for all tilts on the east-west axis.

Both reconnaissance and precise methods of finding optical directions can be used. Reconnaissance methods, often used in routine identification of plagioclase composition and twin laws, and in petrofabric work, must be rapid and accurate to about ± 1–$2°$. Precise work, mainly used in careful mineralogical studies, demands accuracy to a fraction of a degree with speed of measurement a minor

consideration. A statistical study of the following methods, some of them new to universal-stage work, was undertaken to see if any method combined speed and accuracy: (1) use of interference figures, (2) directly rotating to the position of maximum extinction, (3) finding the midpoint between the two positions on either side of the position of maximum extinction where the first perceptible illumination occurs, (4) Wright's method of rotating the upper nicol slightly from the true crossed position in order to test the maximum extinction position, and (5) the slotted ocular, cap analyzer, and special accessories.

FOCAL MECHANISM OF THREE KAMCHATKA EARTHQUAKES

William Stauder, S.J.
Saint Louis University, Saint Louis, Missouri

Three Kamchatka earthquakes are selected in order to study the relation between *S* waves and the source mechanism. The methods of *S*-wave analysis which are applied are based on the theory of point sources and make use of the polarization of *S* observed at many stations. For a single dipole with moment source, in a central projection of the focal sphere onto a plane tangent to the sphere at the bottom, the projection of the directions of polarization of *S* determine a family of straight lines which converge to the pole of motion—that is, to the pole of the "auxiliary plane." Alternately, if the poles of the planes of polarization of *S* are plotted on a Wulff net, the locus of the poles determines the trace of the auxiliary plane on the net. Other point sources are also considered.

For two of the earthquakes selected for study the fault-plane solutions had previously been determined from the data of *P* waves. For these two cases no correspondence is found between the observed *S*-wave data and the character of the *S* motion expected on the basis of the given nodal planes of *P*, whether the source be considered as a single dipole with moment or as two superposed dipoles of opposite moments.

For the third earthquake the *S* waves are strongly *SV* polarized. Investigation of the direction of first motion of *P* for this earthquake shows that the *P* motion is compressional along all rays leaving the focus downward. No faulting mechanism can explain this combination of the direction of first motion of *P* and the polarization of *S*. The source mechanism is interpreted as corresponding to a simple force acting almost vertically downward at the source. A reconsideration of the other two shocks shows that these, too, are better explained by a simple force than by a faulting mechanism.

The earthquakes studied all occurred at a focal depth of 40–60 km. The conclusions indicate that in some earthquakes a mechanism not previously detected may operate at these depths.

S WAVES: ALASKA AND OTHER EARTHQUAKES

William Stauder, S.J.
Saint Louis University, Saint Louis, Mo.

The techniques of *S*-wave analysis previously discussed are here used to investigate the focal mechanism of four earthquakes. In all cases the results of the *S*-wave analysis agree with published *P*-wave solutions and conform to a dipole with moment or single couple as the point model of the focus. Further, the data from *S* waves select one of the two nodal planes of *P* as the fault plane. Small errors in the determination of the angle of polarization of *S* are shown to result in a scatter in the data of a peculiar character which might lead to misinterpretation. The methods of *S*-wave analysis which in the present instances show excellent agreement with a dipole with moment source are the same methods which in the previous paper and for a different group of earthquakes required a single-force type mechanism.

ENGINEERING NOTES ON THE HEBGEN LAKE, MONTANA, EARTHQUAKE OF AUGUST 17, 1959

Karl V. Steinbrugge
Structural Engineer, Pacific Fire Rating Bureau, San Francisco, Calif.

The Hebgen Lake, Montana, earthquake of August 17, 1959, resulted in spectacular surface faulting and a very large landslide among other major surface effects. While geologic and seismographic evidences of a large shock were apparent, the damage to man-made structures was remarkably small.

Hebgen Dam, about 5 miles upstream from the major landslide which dammed the Madison River, is composed of an earth and rock fill, except that it has a full-height concrete-core wall along most of its main axis. The concrete-core wall settled very little, but the earth and rock around it settled up to 6 feet and contained fissures.

Building damage was unusually slight. A number of log cabins as well as hollow-unit masonry structures were within yards of the fault scarps, and these buildings in general were not severely damaged when not directly astride the scarp. Buildings across the fault were, of course, ruined. Masonry chimneys were generally, but not universally, damaged or destroyed. Some of the log cabins shifted on their foundations, but rarely did they go off their foundations. Masonry veneer fell from some buildings. As has been noted in epicentral regions of other shocks, good construction is more important than distance from a fault.

Bridges located in poor ground areas swung back and forth. In one case the bridge swung at least 15 inches, and this violent motion damaged the reinforced-concrete supporting beams.

DIABASIC AND GABBROIC ROCKS IN THE SOUTH-CENTRAL CASCADE MOUNTAINS OF WASHINGTON

Martin L. Stout
Dept. of Geology, University of Washington, Seattle, Wash.

Diabasic and gabbroic intrusive rocks in a 300-square-mile area of the south-central Cascade Mountains of Washington, 25–40 miles northeast of Mt. Rainier, represent at least two periods of intrusion. The intrusive bodies range from small, tabular dikes less than 1 foot thick to large bodies covering more than a square mile.

The older diabasic and gabbroic intrusions are early Tertiary in age and are at least in part feeders for some of the basalt flows in the Eocene (?) Naches formation. In one place, an intrusive diabase body can be traced almost continuously into a basalt flow of the Naches formation. The intrusive bodies appear to be related in time to similar rocks in the Teanaway dike swarm, approximately 20 miles to the north.

Younger diabasic and gabbroic intrusions, commonly intruding volcanic rocks of Oligocene (?) age, have been traced into some flows of the widespread Columbia River basalt (Yakima basalt) on the eastern and southern margins of the area. It is not known how much of the Yakima basalt had a local source in this area. Many of the younger intrusive bodies have a pronounced northwesterly trend, probably reflecting control by basement structures.

Petrographically, the younger rocks can generally be recognized by relatively fresh pyroxene associated with fresh or altered plagioclase. In the older basic intrusions, the pyroxene is commonly altered, and, in general, kaolinization, saussuritization, and calcification of the plagioclase are more pronounced.

EARTH-STRAIN METER INSTALLATION AT OGDENSBERG, NEW JERSEY

George H. Sutton, Robert W. Metsger, and Jack Oliver
Lamont Geological Observatory, Palisades, New York

A horizontal-component strain meter has been installed 1850 feet below surface in the New Jersey Zinc Company mine at Ogdensberg, New Jersey. A 200-foot fused-quartz sensing tube is located in

an exploration drift through Precambrian limestone at some distance from active mining operations. A recording room adjacent to the tube room and sufficiently large for a substantial recording installation was constructed in the same drift.

A variable-capacitance displacement transducer is being used as the detecting element. Records obtained to date show tidal strains, several well-recorded distant earthquakes, storm microseisms, and slowly varying (of the order of several days peak to trough) signals which correlate with meteorological variations.

Background noise level for periods less than those of the tidal strains is sufficiently low to permit relatively high-sensitivity recording of long-period earthquake phases. Occasional small impulsive signals are observed. These have not been definitely identified but are possibly the result of noise generated in the transducer and/or recorder circuits. Several frequency bands can be observed from the same sensing tube.

A long-period vertical seismograph is also operating in the mine. Installation of instruments to measure other components of strain and complementary parameters is planned.

DIAPHTHORITIC GNEISS IN THE NORTHERN CASCADES, WASHINGTON, AND ITS STRUCTURAL SIGNIFICANCE

Rowland W. Tabor
Department of Geology, University of Washington, Seattle, Wash.

South of Cascade Pass is an interlayered unit of epidote-bearing quartz-albite gneiss and epidote-chlorite-albite schists, all of the low-grade zone. This unit overlies a heterogeneous sequence consisting mainly of biotite schists and hornblende-biotite schists with a few intercalations of marble and metaconglomerate. The diaphthoritic nature of the banded gneiss is demonstrated by medium-grade relict minerals, such as biotite, garnet, and intermediate plagioclase, in all stages of mechanical breakdown and recrystallization to the present low-grade assemblage. The original gneissose structure and layering is well preserved. Zoned epidote gives a possible record of the breakdown of mafic minerals during diaphthoresis. The underlying metasedimentary rocks are of medium grade and show little retrogression except near the contact.

The contact of the diaphthorite and the underlying metasedimentary rocks has been obscured by metamorphic convergence and has been later folded. At one locality, mapped by Misch, retrogression can be proved in the underlying schists where garnet-biotite schist is retrogressively altered to mylonitic mica schists containing chloritoid.

Structural discordance between these two units is demonstrated by the southwest-northeast trending contact of the gneiss across consistent northwest–southeast trending schistosity and compositional layering in the underlying metasedimentary rocks. Thrusting is postulated to explain the structural discordance and the proximity of rocks of differing metamorphic facies and histories.

ALKALI METASOMATISM, HUMBOLDT RANGE, NEVADA

D. B. Tatlock, R. E. Wallace, and N. J. Silberling
U. S. Geological Survey, Menlo Park, Calif.

The Koipato group of Permian and Triassic age consists of about 4000 feet of andesitic rocks overlain by 8000 feet of rhyolitic flow, pyroclastic rocks, and detrital rocks which are pervasively silicified, albitized, and potassium metasomatized. These rocks are exposed over nearly half the 240-square-mile area of the Humboldt Range.

The andesitic rocks were evidently albitized at the time of submarine emplacement, but sodium metasomatism continued, at least locally, well into the rhyolitic stage of volcanism as evidenced by quartz-albite spherulites and veins and intensely albitized rhyolitic tuff beds high in the Koipato section. Na_2O:K_2O ratios as high as 8.0:0.2 are common.

The uppermost Koipato rocks are quartz- and K-feldspar-rich breccias, tuffs, and flows genetically

related to numerous small rhyolite porphyry intrusive bodies. These intrusive rocks cut, but are essentially contemporaneous with, leucogranite intrusive bodies. Possibly they originated from a potassium-rich residual magma of the leucogranite. Albitized rhyolites and andesites near the rhyolite porphyry intrusive bodies are enriched in potassium (and commonly alumina). Albite is generally replaced by K feldspar in the rhyolitic rocks, but locally the intense effects of both albitization and later potassium metasomatism are seen in a single outcrop.

Residual fluids of the rhyolite porphyry intrusive rocks ($K_2O:Na_2O - 7:<1$) increased the K_2O content of some of the rhyolitic extrusive rocks to as much as 12 per cent and increased that of some previously albitized andesitic rocks so that the $K_2O:Na_2O$ ratio is 3.0:1.0.

TWO HOLLISTER, CALIFORNIA, EARTHQUAKES

Don Tocher
University of California, Berkeley, Calif.

Two sharp local earthquakes occurred near Hollister, California, in less than a month: (1) 0232 GCT, December 29, 1959, Richter magnitude 4.7, epicenter just north of Hollister, and (2) 0325 GCT, January 20, 1960, Richter magnitude 5.0, epicenter close to the Vineyard fault-creep station 6 miles south of Hollister. Although both shocks were felt strongly in Hollister, the patterns of intensities differed noticeably in accord with the different epicenters.

The January 20, 1960, earthquake was accompanied by nonelastic surface ground movement in the San Andreas fault zone, as shown by a University of California creep recorder installed to measure movement of one concrete floor slab of a large warehouse relative to an adjacent floor slab. Three millimeters of right-lateral movement took place during the earthquake; the time required for the offset was short, but not measurable because of the slow drum rate of the creep recorder.

Directions of first *P* motion at nearby stations on December 29, 1959, were consistent with right-lateral movement on the Hayward fault, and on January 20, 1960, they were consistent with right-lateral movement on the San Andreas fault.

The earthquake of January 20, 1960, was the sixth earthquake with Richter magnitude 5 or over to occur in the central coast region of California in the past 6 years. In contrast, only two shocks of comparable magnitude occurred in the same area in the preceding 11 years.

GEOLOGIC MAP OF LINCOLN COUNTY, NEVADA

Charles M. Tschanz and Earl H. Pampeyan
U. S. Geological Survey, Menlo Park, Calif.

Since 1956, the U. S. Geological Survey, in co-operation with the Nevada Bureau of Mines, has studied the geology and mineral resources in Lincoln County, Nevada, an area of 10,600 square miles. Mineral production in the county has been approximately $189,000,000. A preliminary geologic map will be useful in evaluating the mineral potential and in guiding exploration activities. Approximately 7 per cent of the map was compiled from published maps; the rest we mapped.

The exposed rocks have been subdivided into 45 map units, which include 1 Precambrian, 7 Cambrian, 3 Ordovician, 1 Silurian, 4 Devonian, 3 Mississippian, 1 Pennsylvanian, 3 Permian, 3 Triassic, 2 Cretaceous or Eocene, and 17 Cenozoic units.

Pre-Jurassic sedimentary, Tertiary volcanic, and Cenozoic unconsolidated rocks each occupy one-third of the county. Paleozoic rocks are widely distributed, but Precambrian and Triassic rocks are confined to the southeast corner.

A Paleozoic miogeosyncline occupied most of the county. Within it as much as 42,000 feet of sedimentary rocks was deposited. These rocks thin to 9000 feet in the southeast corner by onlap of Devonian rocks onto successively older formations on a stable platform area.

Many pre-Miocene (Laramide?) thrust-plate remnants, as much as 16,000 feet thick, characteristically bring older rocks as much as 16 miles eastward over younger rocks that are generally folded into overturned synclines beneath the thrust. The basins and ranges were blocked out by normal faulting, generally in Miocene and Pliocene time, before the deposition of middle Pliocene lake beds.

ORIGIN OF ZONING IN SOME IGNEOUS PLAGIOCLASES

Joseph A. Vance
Department of Geology, University of Washington, Seattle, Wash.

A zonal sequence of oscillatory cores and thin, normally zoned, more sodic rims characterizes plagioclase in many plutonic igneous rocks, especially quartz diorites and granodiorites. The core–rim boundary is usually irregular and embayed, while the corroded core often shows a patchy zoning formed by irregular inclusions of the rim plagioclase.

The oscillatory cores are interpreted in terms of differing rates of diffusion and crystallization leading to recurrent supersaturation of the melt in anorthite adjacent to the individual crystals (Hills, 1936). The abrupt change to normally zoned rims in the zoning sequence reflects saturation of the melt in volatile materials. After saturation, agitation by the escaping volatiles promotes diffusion within the melt, equalizing the rates of diffusion and crystallization. This prevents further supersaturation, permitting uninterrupted crystallization of the rims. When a magma attains saturation during its ascent, continuous crystallization after saturation is further necessitated by diminishing solubility of volatiles in the melt with declining pressure.

The resorbed oscillatory cores support the interpretation that saturation occurred largely in response to falling pressure accompanying rise of magma. The envisioned sequence of development is: (1) deep-seated crystallization of oscillatory plagioclase *in situ* by the diffusion-supersaturation mechanism; (2) rise of the magma which with falling pressure terminates crystallization and initiates resorption; (3) continued rise which leads to saturation and separation of the volatile phase halting resorption and causing crystallization of the normally zoned rims.

Formation of the oscillatory zoning through pressure changes caused by recurrent release of volatiles explains neither the resorption, the change in zoning, nor its timing.

STROMATOPOROIDS OF THE KENNETT LIMESTONE, SHASTA COUNTY, CALIFORNIA

R. H. Waines
Department of Paleontology, University of California, Berkeley, Calif.

A stromatoporoid fauna is present in the Kennett limestone in the SE¼ NE¼ Sec. 22, T. 34 N., R. 5 W., Mount Diablo Base and Meridian, Shasta County, California. Detailed collecting shows that Coenostea occur in varying degrees of abundance and in diverse attitudes in the upper 150 feet of a section of biofragmental limestone approximately 215 feet thick. Examination of thin sections from more than 70 specimens demonstrates the presence of at least eight species. The genus *Anostylostroma* is represented by four species, *Amphipora* by one species, *Parallelopora* by two species, and *Stromatopora* (?) by one species. Most of the species seemingly have not been described. Although none of the genera is limited to the Devonian, the acme of *Anostylostroma* and *Amphipora*, as known, is Middle Devonian. The stromatoporoids, therefore, indirectly support previous suggestions of a Middle Devonian age for the Kennett limestone at its type locality.

STRUCTURAL FEATURES OF THE HUMBOLDT RANGE, NEVADA

Robert E. Wallace, Norman J. Silberling and Donald B. Tatlock
U. S. Geological Survey, Menlo Park, Calif.

The structure of the Humboldt Range in northwestern Nevada is an elongate anticlinorium of Permian and Triassic rocks that is overridden by thrust plates and nappes made up of rocks of Triassic and Jurassic age; these are cut by a system of normal faults, some of which form range boundaries.

The anticlinorium, composed of a set of canoe-shaped anticlines, trends slightly east of north across the more northerly trend of the range itself. Segments of the normal faults bounding the range diverge widely from the northerly trend, and at least one segment cuts diagonally across the range. Pliocene and Pleistocene fanglomerates derived from an ancestral Humboldt Range have been broken by normal faults and progressively tilted. Block faulting has continued into the Recent.

A synclinelike structure in the southern part of the range is interpreted as a segment of a large recumbent anticline overturned from southwest to northeast. The overturned block is further cut by a net of closely spaced normal faults. In the northern part of the range there are blocks that override from northwest to southeast and others that override from east to west. Both the north-trending folds in the main part of the range and the thrusts and nappes were developed after Early Jurassic time and probably before early Tertiary time.

TWOFOLD DIVISION OF THE COLUMBIA RIVER BASALT

A. C. Waters
1910 Willamette St., Eugene, Ore.

The Columbia River basalt has been sampled by 29 stratigraphic sections.

Petrographically, and also stratigraphically, the rocks assigned to this formation by Merriam, Lindgren, and Smith are divisible into two distinct varieties. The older, widespread in the Imnaha and John Day regions, is characterized by about 5 per cent olivine, a silica content of 47 to 50 per cent, and by notably higher Al_2O_3, MgO, and CaO than the younger. Many outcrops have a characteristic "greasy" appearance because of the presence of saponite after olivine and of nontronite and other clay minerals after chlorophaeite. The basalts at Picture Gorge and Turtle Cove, described by Merriam in 1901, are typical.

The younger basalts are characterized by more than 20 per cent of tachylyte, little or no olivine, a silica content of 53–54 per cent, and by notably greater amounts of K_2O and TiO_2. The Yakima basalt, defined by Smith in 1901, is of this kind, and so are nearly all the basalts north of the John Day and Imnaha areas. In the lower part of the Imnaha canyon these younger basalts rest with distinct unconformity on flows of the older Picture Gorge type.

Because of their separation in time, differences in chemical composition, and particularly because of the absence of transitional varieties between them, these two divisions of the Columbia River basalt are considered to be products from separate magmatic hearths, and not differentiates of a hypothetical uniform magma.

ECLOGITE INCLUSIONS IN SERPENTINE PIPES AT GARNET RIDGE, NORTHEASTERN ARIZONA

K. D. Watson
Department of Geology, University of California, Los Angeles, Calif.

Garnet Ridge, on the Colorado Plateau approximately 35 miles northeast of Kayenta, Arizona, is a low ridge of Jurassic sedimentary rocks perforated by four serpentine pipes. The pipes contain abundant xenoliths, including many derived from the Paleozoic sedimentary rocks and the igneous

and metamorphic basement below. Malde (1954) determined that the fine matrix containing the xenoliths consists mainly of serpentine, less abundant calcite and chlorite, and minor amounts of olivine, chromian diopside, biotite, pyrope, and montmorillonite.

Eclogite inclusions are sparse among the xenoliths. The eclogites are medium-grained rocks in which bright-green pyroxene and pink to red garnet are visible megascopically. The eclogites range in density from 3.3 to 3.6. Commonly they consist of about two-thirds pyroxene and one-third garnet. Most eclogite inclusions are essentially massive, but some show a distinct alignment of the pyroxene prisms.

The pyroxene has been identified as omphacite. Rutile is a minor accessory in all eclogites examined; apatite and white mica occur in a few. Lawsonite was identified in some eclogite inclusions, and in a few it ranks as a major constituent.

PALEOZOIC-MESOZOIC FRAMEWORK OF THE CORDILLERAN GEOSYNCLINE

Harry E. Wheeler
Departmentt of Geology, University of Washington, Seattle, Wash.

The western Cordilleran Paleozoic–Mesozoic stratigraphic record appears to comprise 10 regional unconformity-bounded sequences, two of which are believed to correspond in framework content to the craton-centered sequences of Sloss *et al.* (1949) and Sloss (1959). These sequences may be roughly designated as: (1) uppermost Precambrian to lower Ordovician (= Sauk); (2) mid-Ordovician to lower Devonian (= Tippecanoe); (3) mid-Devonian to lowermost Mississippian; (4) upper Mississippian to lowermost Pennsylvanian; (5) lower Permian; (6) upper Permian; (7) upper Triassic to lowermost Jurassic; (8) mid-Jurassic to lowermost Cretaceous; (9) mid-Cretaceous; and (10) upper Cretaceous to Paleocene.

"Cascadia," as an exclusively western positive, apparently did not exist prior to Mississippian time but was present intermittently from then until late Triassic.

The so-called "Manhattan geanticline" as a "late Paleozoic positive" is believed to have been merely the easterly margin of the intermittent "Cascadia." Such an intrageosynclinal positive is interpreted, however, for the interval from mid-Jurassic to early Tertiary.

The regional depositional episodes manifested by the sequences were characterized by much greater environmental uniformity and lateral extent than previously interpreted. Most of the innumerable stratigraphic discontinuities in the present record are the consequence of the differential effects of the dozen or more, Phanerozoic, post–depositional, tectonic (deformation–metamorphism–nondeposition-erosion) episodes up to and including the presently continuing Cascadian orogeny.

MAXIMUM VERTICAL GROUND DISPLACEMENT OF SEISMIC WAVES GENERATED BY EXPLOSIVE BLASTS*

D. E. Willis and James T. Wilson
Willow Run Laboratories, University of Michigan, Ann Arbor, Mich.; Department of Geology, University of Michigan, Ann Arbor, Mich.

An approximate first-power relationship was found between the maximum vertical component of ground displacement and the charge size from a number of quarry shots. The maximum vertical ground displacement, normalized to the Rainier (1.7 kt) underground nuclear shot, is presented for a

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series of explosive shots ranging from 1 ton to 19 kilotons and at distances of 1 to nearly 1000 km. The following empirical equations were found to fit the observed data:

$$A = \frac{0.65 \pm 0.15}{R^{3/2}} \text{ from 1 to 100 km,}$$

$$A = \frac{(0.013 \pm 0.003)e^{-(0.0072\pm.0003)\,R}}{R^{1/2}} \text{ from 100 to 1000 km,}$$

where A is the maximum vertical component of ground displacement in centimeters and R is the distance in kilometers.

STRATIGRAPHY AND PALEOBOTANY OF THE WESTERN CASCADES OF OREGON

Jack A. Wolfe
Department of Paleontology, University of California, Berkeley, Calif.

The two major groups of volcanic rocks in the western Cascades of Oregon—the Little Butte [Mehama] volcanic rocks, and the Sardine [Rhododendron] volcanic rocks—contain abundant plants. In the Little Butte, five floral zones can be recognized, ranging in age from middle Oligocene (Lincoln "stage") through early Miocene (Temblor "stage", in part). In southern Oregon, all the floras indicate an Oligocene age. To the north, the Little Butte appears to be progressively younger, since in the Clackamas and Columbia Gorge areas only floras of early Miocene age are known.

The Sardine volcanic rocks appear to be of middle to late Miocene age; three floral zones are represented. The relationship of these zones to marine strata is unknown. In terms of mammalian biostratigraphy, the Sardine is Hemingfordian and Barstovian in age. No floras younger than Barstovian are known in the western Cascades proper.

All Little Butte floras, except the early Miocene Collawash, indicate a subtropical climate. The Collawash, which lived on a volcanic upland, contains many species closely related to middle Oligocene forms of Montana and Wyoming. There is considerable evidence that the warm-temperate Miocene vegetation of Oregon was derived not from the north but by extensive migrations from the Cordilleran region. The Sardine floras are composed of species either conspecific with, or derived from, Collawash species. Cooling climate during the Miocene was evidently a factor, along with the rising western Cascades, in allowing the development of an extensive coniferous forest in the highlands.

EOCENE SPECIES OF THE GENUS *BALANUS* (CIRRIPEDIA)

Victor A. Zullo
Department of Paleontology, University of California, Berkeley, Calif.

The Eocene has long been recognized as the time of the first occurrence of the genus *Balanus*. Several species have been described from the Eocene of Europe and the eastern United States, but *Balanus unguiformis* Sowerby from the Auversian and Bartonian of England has long been the only Eocene species based upon opercular plates. The opercular plates are necessary for specific determination, and species described solely from the outer shell are unrecognizable at present.

A new species of *Balanus* from the type section of the Cowlitz formation in southern Washington is represented by both opercular plates and shells. This is the second record of Eocene barnacles on the Pacific Coast and the first time the opercular plates have been found. This species is interpreted as being morphologically more primitive than the English *B. unguiformis*. Both species may be assigned to the subgenus *Hesperibalanus*, although *B. unguiformis* has previously been referred to *Balanus s.s.* *Hesperibalanus*, characterized by solid parieties, appears to be the ancestral group from which the later members of the genus *Balanus* with tubes in the parieties were derived.

The pre-Eocene history and derivation of the genus *Balanus* are unknown, although possible ancestors have been found in Cretaceous deposits. However, additional collections, with emphasis on opercular plates, are needed before the ancestry of *Balanus* can be adequately determined.

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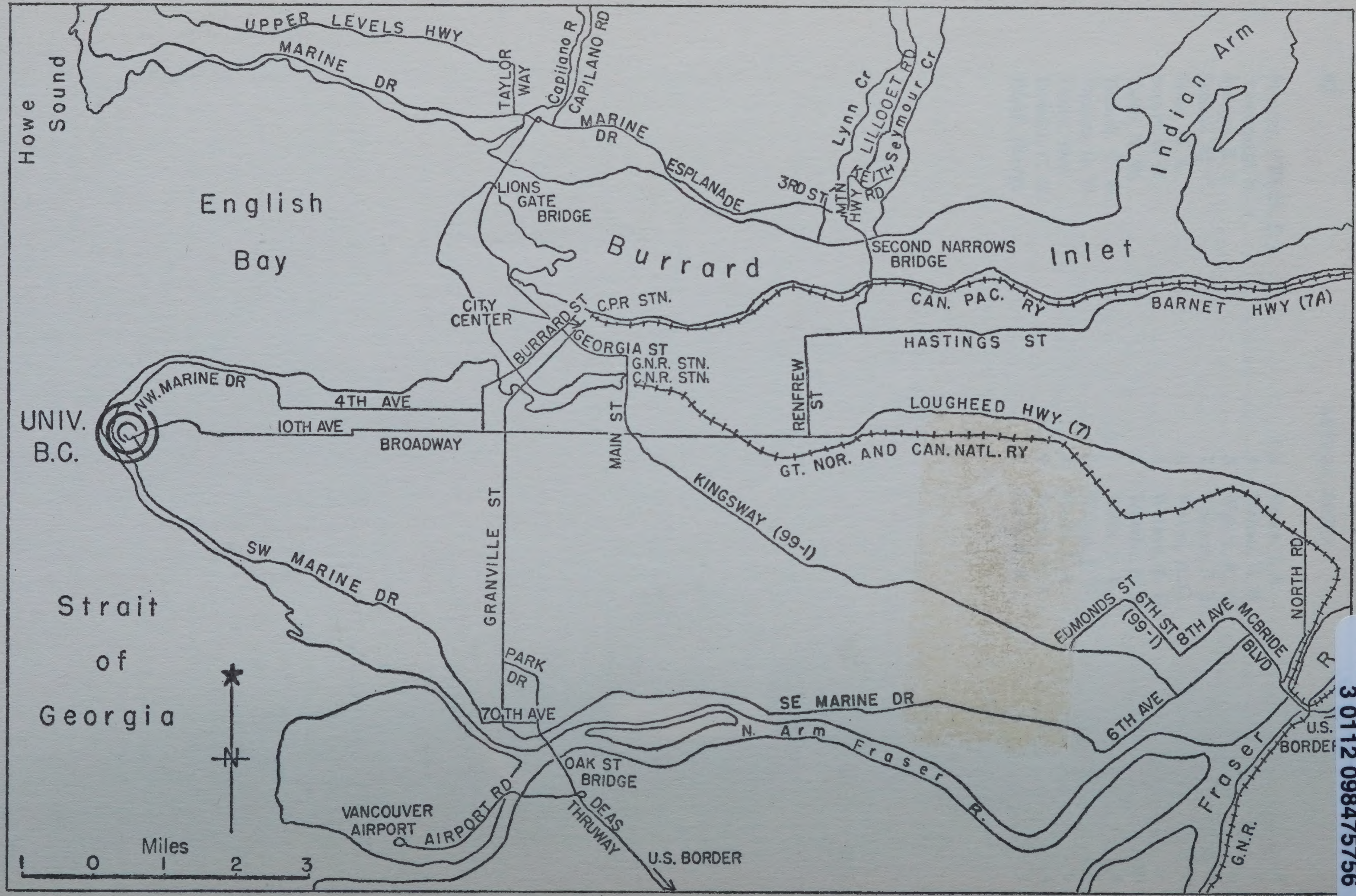

VANCOUVER AND VICINITY